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CONTENTS

CAPITAL - FUNDAMENTAL PRODUCTION FACTOR IN MINING BRANCH

SORIN-IULIU MANGU [1]

Abstract: *In relation to other development projects within an economy, mining projects (specific to underground or day-to-day operations and preparation) have specific key features, namely:*

- high volume of capital investment;

- significant losses due to the immobilization of the invested capital (due to the relatively long periods of realization of the years);

- long-term recovery of the invested capital;

- small (or even non-existent) profits;

- increased use of the capital production factor;

- high value of specific investment.

A simple review of these peculiarities reveals their connection with the capital production factor.

Keywords: *factors of production, capital, mining, mining projects.*

1. CAPITAL INVESTED INTO THE MINING PROJECTS

In mining projects, the classification of capital expenditures can be done according to several criteria. One of the most used is the nature or destination of the invested amounts, a criterion in relation to which we differentiate [3]:

-investments general;

-investments in common surface installations and premises;

-investments specific to the operating unit (underground or up to date);

-Investments specific to the plant.

General investments (common to a complex facility, mines plus preparation plant) consist of access to the premises (roads, railways), preparation of the land (gutters, floodplains, drainage), power supply, water supply, studies and documentation, exploration projects, exploitation projects, feasibility studies, project supervision during the execution period, temporary construction, personnel costs in the project start phase, working capital funds.

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Investments in common surface installations and enclosures consist of ancillary services (workshops, warehouses), enclosure roads, conveying infrastructure, mining colony (for isolated mining purposes).

Investments specific to underground facilities consist of machinery and technological equipment for underground exploitation, well drilling, opening and preparation works until entry into production, well drilling equipment, compressed air installations, underground atmosphere maintenance facilities.

The investments specific to the preparation plant are made up of foundations for the preparation plant buildings, preparation plant halls, ore crushing, storage and transfer facilities, grinding and storing equipment for grinding, concentration units, drainage and filtration), concentrate storage and concentrate loading units, ponds or tailings ponds.

These investments add, in general, the costs previously incurred for the research of the deposit and the accumulation of a sufficient amount of information to allow a proper substantiation of the decision on the start of the development works.

For capital needs, capital expenditures can be grouped in different ways. Such aggregation highlights the causes, the factors that influence the level of capital expenditures. Such a grouping comprises, for example, four major categories of capital expenditure [3], namely:

-general infrastructure: communication, access and transport routes, colony or mining town, to which are sometimes added pre-discovery for quarries and equipment and works for access to the deposit (are capital expenditures influenced mainly by geographic position and geological structure deposit);

-mining equipment, the main factor of influence being the nature of the useful mineral substances and the exploitation methods applied;

-production plant (halls and equipment) where the main factor of influence is the technological flow of preparation and capacity;

-other capital expenditures, the main influence factor being the degree of industrialization of the area where the project is located.

2. A PARTICULARITY OF THE CAPITAL INVESTED INTO THE MINING PROJECTS: ”SUNK” COSTS

In order to reach a mine in operation, with a specific frontier line on which coal production is extracted, a long process is under way, which has, as a rule, started many years ago by exploring and exploring an identified reservoir, continued with mining and surface and underground constructions to achieve a first exploitation capacity, and finally with the preparatory work, until the delimitation of demarcation fields and the beginning of the extraction process from these fields. In parallel with the construction, opening and preparation works, there are equipped with machines and equipment specific for the execution of works and for the abatement fronts and the realization of specific installations and installations. There is also an endowment of machinery, equipment, and installations of auxiliary and serving activities. Throughout this time, resources are consumed, capital is being invested, and some costs are already borne by the one who finances commissioning. The mine once achieved has a heritage stemming from previous decisions and actions, which have an important feature: the greatest share of this heritage is worth not by the costs incurred but by the results obtained by exploiting the reserves. This means that a pit which cost 5,000,000 lei is zero if the exploitation ceases to exist, if the reserve that was expected is not confirmed, or if it is exhausted, and by damping nothing could be recovered. The initial cost of the well is a past, final cost - it is a "sunk" cost, according to English economic terminology.

The shaft and many other works, constructions and mining facilities, as opposed to a universal lathe in the mine workshop, do not offer rescue or resale value, but only a utility value through future profits, in the case of profitable or eventual activity through cost savings, in the case of an activity that recovers its current operating costs and does something extra with them by selling the products of exploitation.

This economic feature of capital participation in mining is essential for the proper assessment of patrimony in investment decisions, commencement of business or activity restraint, and reinvestment to maintain the business or to invest further in the development of the business.

3. SPECIAL ASPECTS OF FINANCING THE MINING PROJECTS

Relative to the past economy, the financing of mining projects is not worth studying. The state was the sole owner of the mineral and earth resources and, at the same time, the only financier of the mining projects. Under the conditions of the new Romanian economy, even if the ownership structure of the mineral resources has not changed, the state remains the sole owner of them, the financing of the mining projects has gained new dimensions, more and more frequently talking about concession and partnership.

Securing the necessary capital to develop and bring to the production situation a mining perimeter is an essential requirement for the success of a mine action or a mining project. Almost everywhere, the time has passed when a mining perimeter was able to ensure self-financing from the very beginning (rich and surface deposits). What is characteristic of the current stage is that for a good period of time, for years, capital must be advanced without it being able to produce for its recovery and for profit.

For the success of a mining project, the following factors are essential: mineral (raw material base, reserves), market, money, management. Among these factors, the weight of the third M - capital funds has increased, the money needed to convert a prospecting or search into a deposit from which to extract mineral raw materials. Mining is no longer the domain of the small entrepreneur. It was sometime in history, but this time, when a single man with money hired a prospect to search for and discover the fields, he passed. This stage has been replaced by so-called prospecting or prospecting syndicate groups run by an entrepreneur with considerable practical experience and considerable knowledge in the field, with good knowledge of the entire team. For some geographic areas and types of substances, this formula does not meet, and it has already been necessary for the state to take over the funding of these risky actions of search, prospecting. Neither third world countries can afford "go and search" concessions.

In this context, the problems of a potentially valuable mining perimeter owner, which also has the money needed for the investment, materialize in:

-justifying the need for investment for exploration and development (quantification of reserves, opening);

-the justification of the economy of the future mining enterprise in terms of size, capacity, reserves, exploitation time and level of integration (up to what stage of mining processing will the future mining enterprise go).

A potentially valuable mining perimeter owner, who does not have the money to carry out the project, has several problems, namely:

-the two above mentioned, necessity and economy;

-at the same time, such a landlord must be able to present the results of geological research in such a way as to convince a presumptive investor that the respective mining industry will produce an attractive profit. This is done by providing authentic information, complete and well documented documentation, intelligent analysis, fairness.

From the point of view of the financing of the mining investments, one can speak of the three major phases of the process of leading an uncovered, partially researched field, to the mining operation in operation, namely:

-exploration and exploration, phase in which geological conditions and the existence of promising mineralization are determined. The money required to be invested is relatively small but totally at risk;

-counting and proving of reserves, phase involving drilling and / or underground mining and opening works to establish tonnages and contents suitable for profitable exploitation. The amounts invested are increasing, the risk is slightly lower, but it remains high. The objective is to reach a quantity of reserve cantonated under geological conditions and with quality features, content that justifies investments in a first mining unit: mine or quarry. In Romanian practice, this phase is known as detailed exploration, and has always been funded solely from the budget, based on detailed exploration projects that have been finalized with documentation for the approval of reserves. This is the main piece on the basis of which the project of the future mining enterprise must be supported (reserve is provided). The reserve, in quantitative terms, must justify the minimum investment funds needed for a capacity variant that provides return, return, acceptable subsidy;

-the development and construction phase usually involves both mining utilities (construction, underground works, installations, roads, workshops) as well as preparation and even metallurgical refining facilities, depending on the integration decisions.

From the point of view of the mining project, it is obvious that the three phases take place when it is considered that further financing from one phase to another means a decrease in the risk for the new capital invested. The risk is, from the point of view of the project, the basic issue in continuing financing. From the investor's point of view, the higher the risk, the higher the cost of financing, and the share of the future mining company's share capital to be claimed by the investor will be higher. Under market economy conditions, financing issues need to be addressed in the context of the relationship between the two participants: the owner (the one who tries to "sell the deposit") and the investor, that is, the firm or group of companies that takes the risk of securing capital for the project. Within this relationship, the owner must already be recognized his contribution until the appearance of an outside investor is in question. This contribution is actually an "investment" of the owner in one or more ways, namely:

-secure ownership control;

-containing with time and effort knowledge and skill for discovery of reserves;

-to make real money by investing money, in order to establish a basis for information about the presumed value of the mining property.

The owner must be given a perimeter value that is not reduced to the amounts actually spent but also to the other two components. The value that is recognized to the owner is constituted as part of it in the share capital of the future mining enterprise that will be realized in the third phase and will enter into operation after this phase. In the two previous phases, the actual construction of the mine and the plant, the level of risk is obviously high, and the financing usually takes the form of risk capital. This share of social capital essentially involves a percentage or percentage that the investor recognizes as the owner. Thus, in the conditions in which Romanian mining will proceed to concessions or partnerships, an assessment of the value recognized by the owner will have to be made as a basis for the share assigned to it in the share capital of the future joint venture.

The owner's contribution in terms of time, money and other, together with the results obtained through such contributions, is considered important in determining the percentage of the share capital that the owner can reasonably claim when accepting a partnership in which large amounts of risk capital come from an outside investor. If the exploration and development of the mining facility is already successful, sometimes it is possible that part of the investment funds needed for plant and equipment are financed by mortgage bonds or a combination of these and ordinary ones, with the possibility of converting these bonds in shares, in time and price set. Such a funding path can be applied in the case of already dimensioned units, which are in charge of the exploitation processes, with good management, proven by the previous activities, which is the case with already consolidated mining companies. When the need for funding arises, regardless of whether the project is in the prospect, exploration or construction stage, it becomes necessary for the valuation to proceed in a reasonable reduction, in precise terms, of the estimated profits from the assessment of the risk factors.

The risk is determined by internal factors, the project's own, and external factors. Internal factors are those who derive or directly look at the project, taken individually, and its position, its place in the present mineral resource economy and the foreseeable future. A responsibility that can not be avoided by the owner concerns mining perimeter information, which he must present in a mature material and in a form proving competence in the form of a report known as a pre-feasibility or feasibility study. Such a mining property report should highlight verifiable aspects, omitted issues, distinguish between exact and approximate parameters, and determine the degree of uncertainty for the approximate factors. Based on these data, potential profit can be determined or estimated. In order to record success during its exploitation period, a mining operation must obviously ensure "payment" for:

-her purchase price;

-expenditure on development;

-its exploitation, operating costs;

-the minimum return to the invested capital;

-a certain overlap.

External factors are those that act outside the control of the owner outside the perimeter, but are not less important for the project. These factors relate, first of all, to the capital market, thus to the risk capital demand and supply. In this respect, the following factors act:

-basic economic opportunities (conditioned by the political climate);

-monetary and financial conditions, such as credit volume and availability in general; interest rates;

-concurency of other types of projects looking for risky capital, such as the oil industry, the chemical industry and others.

Obviously, successful financing of a mining project is most likely to occur when external and internal circumstances are favorable, and foreseeable difficulties and costs will be diminished as a result of the favorable action of both categories of circumstances.

In financing mining investments, the owner will have to provide investor motivation and initiative, and his / her success chances will increase not only by carefully preparing the information on internal factors but also by evaluating, competently weighing the external factors that will enter into the final evaluation , in determining the final results.

4. CONCLUSIONS

In the synthetic form, the main conclusions that can be drawn are:

-the concept of "resources" in the general sense expresses the state of availability of goods (tangible or intangible) without, however, uniquely associating them with a certain use;

-"resources" are transformed into "factors of production" by attracting them into a concrete use (only "resources" brought into active state become "production factors");

-the evocation of economic thinking records the existence of many debates on the number and structure of the factors of production;

-the concept of French economist Jean Baptiste Say, according to which the factors of production are represented by the original tangible resources, "labor, land and capital", was unanimously accepted in economic theory;

-industrial development has forced the widening of the system of traditional production factors by taking into account the so-called production neofactors (technologies, technical progress, information, scientific research, entrepreneur's ability, managerial capacity, etc.);

-in order to be deployed efficiently, any economic activity requires the prior accumulation and use of reproducible goods, ie of the "capital" production factor;

returning to the invested capital is the main decision criterion in projects with long-term capital investments and ignoring it can lead to erroneous decisions, generating major imbalances in a branch or even the national economy as a whole;

-in the mining projects, the classification of capital expenditures can be done according to several criteria, the most used being the nature of the investments and the factors that determine them;

-the capital invested in the mining projects presents a distinct feature: it is almost entirely in assets with no transfer value (mining works, special constructions and specific installations);

-in any decision, from the point of view of the valuation, the specialized mining assets have a distinct feature: they have value not through the costs incurred, but through the results obtained from the exploitation of the reserves of useful minerals;

-reported to the economy of the past, when the state was the only investor in the mining sector, the financing of mining projects is not worth studying;

-economic practice has shown that for the success of a mining project, four factors are essential: the mineral raw materials base, the mining product market, the capital needed for investment, the management;

-from the point of view of investments in mining projects, one can speak of three major phases of the process by which a discovered, partially researched field is brought into the mining operation situation: prospecting and exploring, quantification and probation of reserves, development and construction of utilities;

-the transition from one stage to the next presupposes a decision, always in other conditions in terms of available information, but with need for financing (needed capital) increasing.

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IMPORTANCE OF THE COSTS IN EVALUATING THE MINING PROJECTS

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Abstract: *From the perspective of the use of production factors, mining projects are projects with long-term capital investments. Irrespective of the concrete form of financing, the sources of funding or the timing of the resource consumption, or the profits generated, the evaluation of these projects always requires consideration of the remuneration of the capital invested. Mining projects can target the development of new perimeters or the continuation of the work of some businesses in operation. Even if each of these situations presents particularities in terms of evaluation, the importance of the cost issue involved is common. For the needs of the economic and financial evaluation, the realization and subsequent functioning of a mining project can be translated into a series of cash flows, in which distinct (in terms of content, moment of production and significance) are output flows, resource consumption, expressed as costs.*

Keywords: *mining, mining projects, costs, evaluating.*

1. CAPITAL EXPENDITURES

Capital expenditures are organically linked to the concept of investment, being known, at least, in the economic theory and practice in Romania, under the name of investment expenditure. Even if there are three different ways of defining the investment - accounting, economic, financial - for our purposes, the general meaning of the concept is important, according to which the investment represents "an expense likely to bring in the future an advantage, many successive future periods" [6] .

Thus, in our opinion, investment expenditures in mining projects can be considered as all the expenses incurred in bringing a mining perimeter to a certain production capacity, as well as the subsequent expenses that are involved in the increase in production capacity.

In the mining design practice of the institutes in Romania, only one method is used to estimate investment costs, antecalculation of foreign exchange (the expenditure being estimated according to the structure of the general estimate). However, the method presents a severe limitation and becomes applicable only after the design stage

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has been completed, provided that an estimate of investment costs may also be necessary and at a stage where an execution project or other design documentation has not been developed yet. For such situations, specific methods for estimating investment costs are applied abroad, namely [3]:

-method based on analogy with existing mining enterprises and / or production capacities;

-the bid analysis method;

-the method based on modeling the main types of expenditure according to the most important parameters that influence them.

Some clarification about the last method is required. Its application is based on taking into account the main parameters that determine the level of investment expenditures in the mining projects, namely: the daily gross mass production (for the underground mining and preparation plant), the daily mining mass production plus the tailings (for the quarrying unit), the section and the depth (for wells), the type of equipment (for energy consumption). Considering these parameters as the determinants of the value of investment expenditures, in the former USSR institutes and the United States Mines Bureau, the analytical or empirical relationship of the value of investment expenditure items was made. Until now, there is no such approach in our country, although the application of the method is possible. A methodology such as that used in North America, for example, employs empirical analytical and statistical models and relationships that allow both the direct estimation of investment expenditure on items and indirectly by applying quotas or coefficients to the value of certain items direct. The use of relations established in other countries in Romania is perfectly possible for their logical and analytical part. It would only entail analyzes and corrections for adaptation to the currency, exploitation methods and deposits in our country.

A particular category of capital expenditure is so-called environmental expenditure. According to the structure of the general estimate and the methodological specifications for its compilation, the first chapter of capital expenditures also includes environmental expenditures (under the heading "environmental protection arrangements, including restoration of the natural framework after completion of works"). In relation to the definition of the investment concept described above, environmental expenditure does not have the defining feature (expenditure made today for the purpose of obtaining future monetary benefits) unless it is analyzed from the global perspective of the conservation and exploitation of natural resources (according to which the existence of a certain natural environment, which can be admired, is beneficial, rather than material in nature). Moreover, environmental expenditures, almost all of them, are incurred at the end of the economic life of the mining project, being imposed by the legislation in force and not by future profit opportunities. In these circumstances, we believe that in the process of estimating the elements necessary for the evaluation of the mining projects, the environmental expenditures must be devoted to a separate chapter, their classification in the structure of the investment expenses being unjustified.

2. OPERATING EXPENSES

Operating expenses, also called operating expenses, are the normal expenses generated by normal operation of the mining enterprise, which do not include either capital expenditures or maintenance costs.

In mining projects, the grouping of operating costs can be done according to different criteria. If design practice in Romania are commonly used two ways to group (the primary elements of expenses or items of calculation) [6] abroad, the most widely used criterion seems to depend on the volume of production [3] from this point of view distinguishing:

-direct costs (determined by the volume of production): Expenditure with the execution and maintenance personnel assigned to the actual exploitation of the reserves, expenditures on consumables (mining timber, timber, wire mesh, explosives, staples, etc.)), utilities (electricity, water), spare parts expenses;

-indirect costs (independent of production volume): expenses for functional and administrative staff, other administrative expenses, expenses for geological research;

-general common costs (jointly shared by several mining companies that are part of the same organizational structure - Autonomous Registry or National Company): Outlay, Supply, Design, Expenditure of the Central Administration.

Depending on the need for analysis and interpretation, operating expenses can be grouped in other ways. For example, when the grouping criterion is the place of production, costs of the actual mining unit (mine or quarry) may be distinguished, the cost of the preparation plant and the expenses of the central administration. Another criterion of grouping can be the nature of the expenditure, in relation to which can be identified expenditures with materials, personnel expenses, utilities expenses, expenses with services provided by third parties, general expenses.

Estimating operating costs involves, first of all, identifying the parameters that determine their size. The number of parameters is not very high, the most significant being:

-productivity of work in different operations, phases, processes (determined by working conditions, machinery and materials used);

-staff salaries and various salary-related expenses;

-the exploitation methods used (for the mine);

-prepared process (for the preparation plant);

-structure of the enterprise (for indirect costs and general expenses).

The main methods used in estimating operating expenses are:

-analogy with other mining enterprises, at least for certain operations and / or phases of the technological process;

-modelling certain categories of expenditure according to the appropriate parameters;

-the detailed analysis of the project, which can not be achieved entirely in the detail of the engineering stage, so after the decision to build the mine.

The most common method is based on modeling certain categories of xpenditure.

3. MAINTENANCE COSTS

In a very general definition, are those costs that need to be incurred to maintain the production capacity of the mining enterprise. Mainly, maintenance costs are limited to the costs of preparing and eventually replacing machinery on the basis of depreciation funds.

In design practice in Romania, the issue of maintenance costs is not properly dealt with, which is assimilated, depending on the specific situation, to operating costs (eg the cost of preparatory work) or to capital expenditures (equipment replacement and opening new reserves).

Based on the estimated cost of mining preparatory work, the work volumes and the unit costs (per specific workload) stand, while the replacement costs of the machinery can be estimated based on the bid analysis method.

4. EXPENSES WITH TAXES AND SIMILAR CHARGES

The basis for their determination is the tax legislation of the country in which the project is carried out. A certain national policy on the exploitation of mineral resources (materialized, for example, in the additional charging of activities to exploit non-renewable resources and imposing certain taxes related to the protection of the natural environment or, on the contrary, in granting certain tax facilities to mining enterprises) can significantly influence the levels of this expenditure.

For mining enterprises, given the particular nature of their activities, the Mine Law has established two specific categories of such costs: fees for prospecting, exploration and exploitation activities and mining charges.

5. INTEREST EXPENSE AND LOAN REPAYMENTS

This category of expenditure occurs when the mining project is not entirely financed by equity. For estimation, the clauses specified in the credit agreement (credit amount, credit duration, repayment method, interest rate) are considered. Estimation difficulties can occur when the interest rate on credit is not fixed, but it follows financial market fluctuations.

6. ACCOUNTING EXPENSES

By using in the current exploitation business, the assets of the assets of the mining enterprise suffer a gradual loss of value (a certain wear and tear). The same goes for the passage of time, natural environment factors and technical progress. However, in order to ensure the continuity of the activity, it is necessary to recover the loss of value or the observed wear. Depending on its nature, the loss of value may be reversible or irreversible. From the accounting point of view, the solution is different: in the first case provisions are made (for depreciation), and in the second case the so-called amortization, defined as "the accounting statement of final deduction of the value of the assets due to their use, the influence of the factors natural, technical progress or other causes" [5].

Depreciation, as an expression of irreversible loss of value, can be seen in two respects: accounting and financial. Under the accounting aspect, depreciation is the expense of the exercise of "consuming" a portion of the fixed asset value, reflecting in fact the process of staggering the consumption of the value of the input of the fixed assets over their entire lifetime. From the financial point of view, the depreciation is intended to provide the necessary financial resources for the replacement of immobilized assets that have been decommissioned (as a result of the expiry of the normal use period or other causes).

The issue of depreciation of fixed assets is regulated by law. Thus, depending on the concrete conditions of each patrimonial unit, one of the following calculation systems can be chosen: linear depreciation, degressive depreciation, progressive depreciation, accelerated depreciation (the use of degressive or accelerated depreciation systems can be one of the fiscal support instruments of the mining activities). In the case of mining enterprises, a specific aspect appears. Thus, for all buildings and special constructions the use of which is limited by the amount of mineral reserves, the depreciation is calculated on the mining unit, depending on the volume of the exploitable reserves (recalculation is made annually if there are changes of at least 10 % in the volume of exploitable reserves, five to five years in underground or surface mining enterprises and ten to ten years in minefields exploiting haloside deposits).

In its accounting form, depreciation is a cost of capital usable in financial assessments, but improperly used in design, decision making, and economic analysis. But there is an economic cost of capital that would come close to what is meant by damping. This cost is called depreciation [2].

As the law provides, the depreciation can only by chance reflect the true cost of using the capital of the nature of the assets, which costs the form of depreciation. Two reasons are essential. In the calculation of depreciation, irrespective of the system applied, the law requires the consideration of a normative term (hours, days, months or years) of operation, by classes of depreciable fixed assets, without explicitly taking into account the concrete conditions in which they will work. The actual loss of value of these assets may, however, be higher or lower, precisely because of conditions different from the average situation reflected in the law. The law also prescribes several methods for calculating depreciation, but the fiscal purpose, to determine the year's result under certain circumstances, outweighs the exact reflection of depreciation. It should be recognized that the statutory provisions on depreciation are predominantly accounting, economic aspects being ignored. Thus, the depreciation law does not take into account that depreciation included in cost (and tax deductible) is not an actual expense but, from the point of view of the enterprise, is an income (a capital that remains in the enterprise) that will be reinvested and will, in turn, produce a comeback. It has been demonstrated that there is only one method that takes into account this reinvestment. We consider that this method, which determines the cost of capital use on the sinking fund, is the only applicable in design. According to this method, the depreciation calculation relationship has the form

$$D = (I - I_n)\frac{r}{(1+r)^n - 1} \tag{1}$$

where: D - annual depreciation;

I - the sum of the capital invested initially (the amount of input of the depreciable asset);

I_n - the value of the depreciable asset after n years of operation;

n - the useful life of the depreciable asset, years;

r - the rate of reinvestment of the recovered capital in the form of depreciation.

In the broad sense, depreciation is the loss of value of property owned (tangible or intangible property) as time passes [1]. The essence of the concept can be better understood if the notion of economic or commercial value is taken into account. From this point of view, a physical asset has value if, by its future use, its owner will obtain a gain in the form of a resulting cash flow either from the use of this asset to produce goods or services or, ultimately, of the sale of the asset [4] (this way of defining a value already raises a particular problem in the process of valuing assets and mining properties, a matter that will be returned to a future paragraph of this chapter). Depreciation is therefore a decrease in value resulting from the diminution of the asset's ability to generate such cash flows in the future by one or more causes, with the passage of time.

Although the fact that depreciation occurs in any economic activity is readily recognizable and recognizable, determining its size is not a simple matter (as suggested by the previous calculation relationship). In fact, the actual amount of depreciation can never be accurately estimated until the asset in question is taken out of service. Impairment is a cost, and should therefore be treated appropriately in economic studies. This problem is resolved by using estimates that may later prove more or less accurate.

Impairment is the loss of value of an immobilized asset between two different times. Theoretically, for an enterprise, the annual cost of depreciation is given by the difference between the initial value of the property and the residual value estimated at the end of the period of use, divided by the number of estimated service years. This simplification is, in fact, taken over in accounting where it is operated with normal service or normal use periods at the end of which the value of the asset is considered to be zero (all depreciation systems are based on the same assumptions of "normal" "Of use and the zero value at the end of this period, the only difference being the way in which value is taken into account over time). Economic considerations also have to be taken into account the effects of the imputed amounts as depreciation costs in the annual statements of expenditure, amounts exempt from corporation tax, which the enterprise may reinvest at certain earnings rates.

7. CONCLUSIONS

From the perspective of project theory, any human activity is dual in character: consumes resources and produces effects. Expanded at the level of replenishment of useful mineral reserves, the previous finding allows for the individualization of several steps, through which successive scrolling may become the object of mining activities (production factor). From an organizational point of view, these stages take place within certain established structures (new or in-service mining enterprises), and decisions to pass from one stage to another (decisions that concern mainly the use of two fundamental factors of production , the deposit and the capital) are mainly based on economic assessments. In other words, at each stage, the problem of evaluating a mining project, characterized by more or less accurate, broader or less extensive information, depends on the stage at which the knowledge of the reserves arrived. Each of these assessments refers to indicators that express the economic efficiency of exploiting reserves, ie comparing the alleged efforts (consumption of financial, technical and human resources) with the expected effects (mining products in certain quantities and with certain qualitative characteristics).

A simple scroll of the basic features of a mining project is sufficient to illustrate the size of the resource hiring that such a project involves. Adding to the peculiarities of the branch, the importance that must be attached to the costs in assessing mining projects is evident.

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THE IMPACT OF THE INTEGRATED TECHNICAL SYSTEM ON THE QUALITY OF CONSTRUCTION WORKS

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GHEORGHE-FLORIN BUȘE [2]

Abstract: The integrated technical system consists in the development of a production technology on the path design – execution – testing – experimentation – homologation. The constructions, as products of human activity, presents a series of characteristics such as: high capital requirements; influenced by a high number of variables, unpredictable due to its long lifetime; has to fulfill the needs of two-three generations which makes standardization difficult and extends the time of experience gathering needed to optimize the products; there are also craft works, despite the technology advancement, where the quality is given by the qualification and skill of the workers; it is difficult to appreciate an optimum ratio between the increase of execution costs for quality improvements and the reduction of the exploitation costs; no defects or scraps are allowed (especially related to stability, resistance, durability and exploitation safety). An integrated construction system means construction design, works and assembly (material and parts supply, construction equipment, qualified workforce) at European level, according to an established schedule, starting from precise cost calculations which do not modify for the entire contract, etc. The construction integrated system uses an advanced technology and is a complete construction system which provides resistance, durability, excellent thermic isolation and sound protection. The result is a predictable and efficient product considering both the used resources and the implied costs. The integrated technical system provides maximum efficiency of the maintenance costs on the entire lifetime of the construction, ensuring substantial cost saves regarding energy, repairs of design modification.

Keywords: *integrated technical system, construction integrated technical system, construction works, construction quality, technical efficiency of construction equipment;*

1. INTRODUCTION

An integrated technical system consists in creating a partnership network composed of organization systems from the domains of research, technology development and innovation, mechanical technologies in constructions, chemical technologies in constructions, mechanical systems execution in constructions, pneumatic-hydraulic systems execution, electronic and automatization systems

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execution for the development of a technologic line towards achieving a product with industrial applications in constructions.

The most quality characteristics are imprinted to the project in the design stage. These are less expensive and easy to modify or replace. In the design stage there can be reviewed certain ideas from the conception stage without significant additional expenses (Buşe, 2017).

Having the right materials and equipment at the quality levels suggested in the design stage removes the risk of getting a low quality product (Ilieş and Crişan, 2008).

The execution stage may contribute to keeping, improving or lowering the project quality. If we have a good design documentation, following all the prescriptions leads to a good project quality, while disrespecting these data leads to a lower quality project. A project with quality deficiencies may be improved if, during the execution, the inconsistencies which lead to this lower quality are traced, and there are suggested modifications of the design documentation which to improve the project quality. One of the most important stages for configuring the quality of a future project is the maintenance stage where we may follow the project operation and the implications of the possible quality deficiencies (Toma and Margarit, 2002).

All the deviations from the required quality of a project lead to additional costs, lower or higher depending on the stage when the deviations are solved (Zafiu and Gaidoş, 2001).

2. THE INTEGRATED TECHNICAL SYSTEM IN CONSTRUCTIONS

The integrated system in constructions represents the most advanced technology in construction systems, giving all the benefits required by a modern technology, design of the most advanced standards. Various design options, high level resistance and excellent capacity of energy loss isolation make from the integrated system in constructions an important technology for present and future constructions.

An important role in keeping the designer requirements and their retrieval in construction quality is given by the integrated or applied technical system (TS). It has to create the balance between the used resources and the performance of the construction, expressed by the methods of evaluating the results of the construction production process (CPP) (fig. 1): work and, consequently, construction quality, production expenses, work execution deadlines, environmental impact, security requirements fulfillment, work protection and safety.

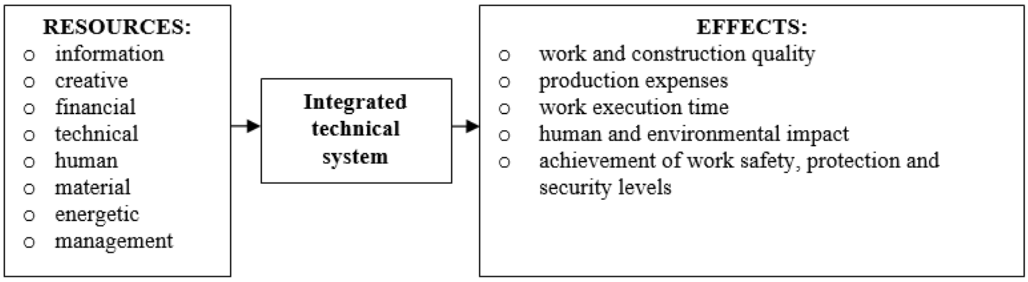

Fig. 1. Construction production process

The integrated TS is determined by the interdependences between the factors from every CPP component (fig. 2): technology and metrology equipments, materials and energy resources, human factors, technology procedures applied, environmental factors.

If we refer to construction quality, we may consider that it covers, due to the integrated TS, the quality of every factor. As it results from the diagram type cause-effect (fig. 3), named also Ishikawa diagram (fishbone diagram), neglecting the quality of any of these factors up to a certain degree will affect the quality of the construction (Zafiu, 2004).

Next we will analyze shortly the main factors of the TS: technologic equipment, materials, human factors and technology procedures.

The term ”technologic equipment” usually refers to the technical endowment used for construction executions represented mostly by technical machines.

No construction activity can take place without the required technical equipment. There are some work categories where the technical processes and its results depend entirely on the capacity of the used equipments, such as concrete works, roads or railroads, etc. Therefore, the problem of the construction technical equipment becomes extremely complex, being connected to the applied procedures and having a large set of specific importance.

Therefore, we consider the requirements for performance level ensured by the technical equipment on two basic trends:

- The fidelity of ensuring the technical quality for the processed and used materials, respectively their capacity of executing specific works in their domain, at the quality level for construction technical requirements;
- The reliability and maintainability, operation safety, ergonomic qualities and environmental protection quality.

Each of the above aspects are found directly or indirectly in the quality of the construction.

It is obvious that the fidelity of ensuring the technical quality for the processed and used material is found directly in the quality of the construction. Especially since it is known that the technical equipment is involved directly in the two components of the construction production process (fig. 2): the processing of materials and construction components in industrial units specialized for production and using them in site works for construction execution.

The low reliability and maintainability influence the construction quality as a result of breaking the normal development of the technical process, which may lead to the impossibility of keeping under control the quality parameters of the work or to the work depreciation in time.

The lack of operation safety may lead to failures which don't affect only the development of the technical process by temporary breakdowns with negative effects on quality, but also lead to partial depreciations of the construction, which will have to be repaired.

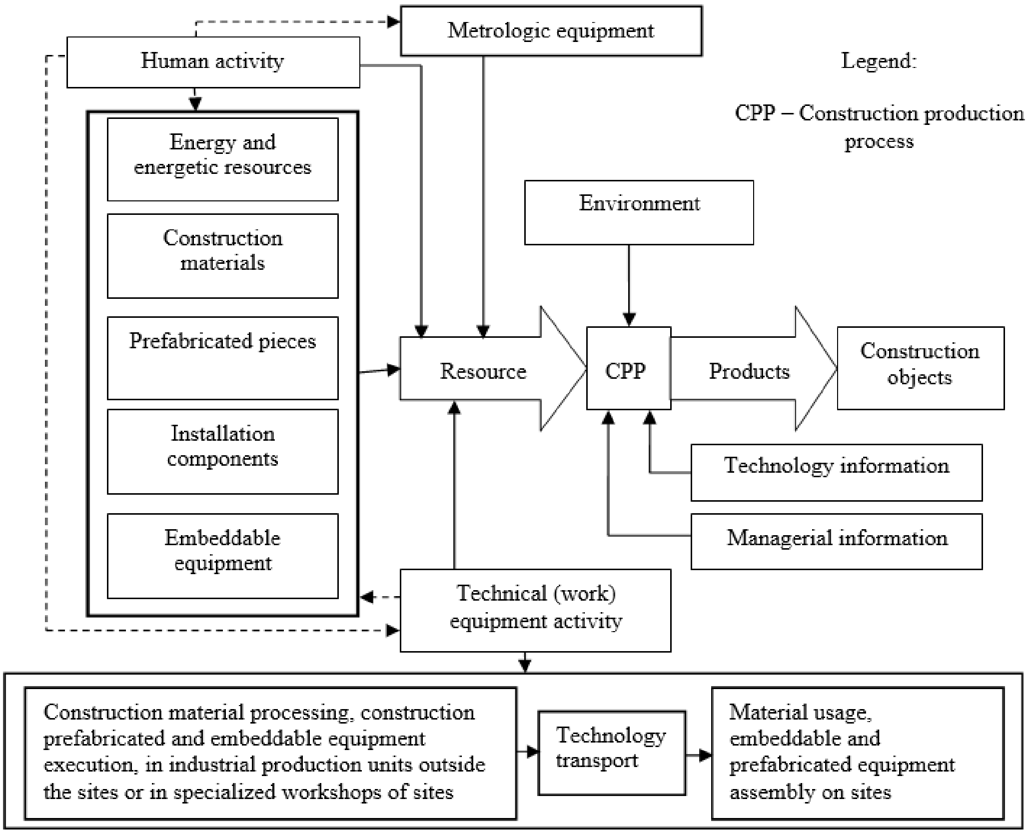

Fig. 2. System factors of every CPP component

This presumes that the technical equipment are permanently maintained, repaired and modernized in order to match the requirements and guarantee the operation safety at nominal parameters.

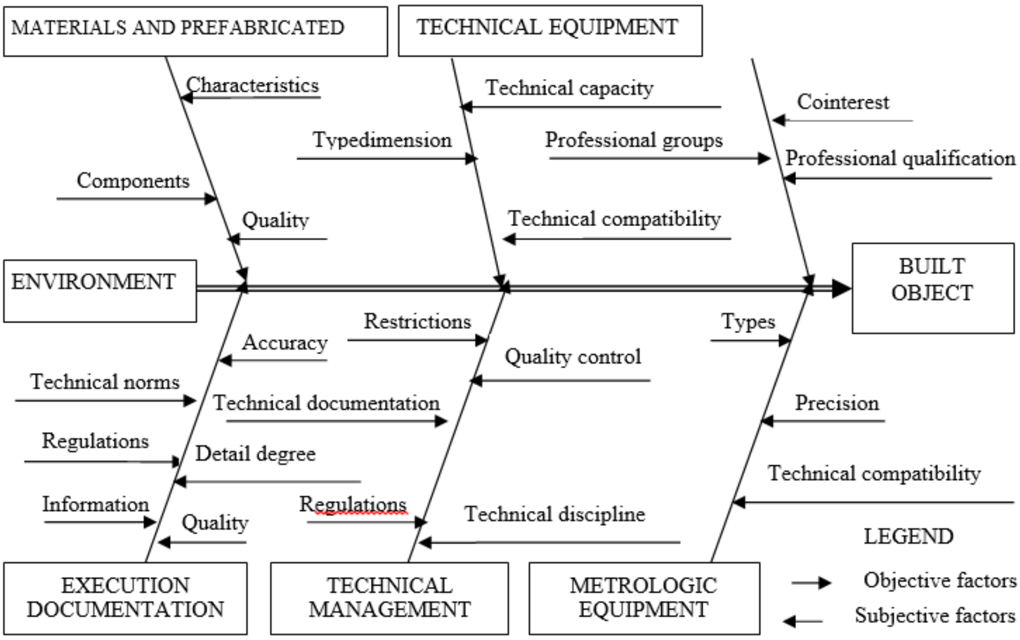

Fig. 3. Cause-effect type diagram

Ergonomic and environmental protection features act indirectly through the human factor, subject of stressing requests with negative effect on the quality of the technical process development and, consequently, on the quality of the construction.

The practical implementation of these requirements is done through a series of actions which consists in the work on the technical documentation and specific regulations:

- the instructions of putting into operation of the equipment, taking into account their complexity, working regime, work nature and other specific factors;
- the instructions for protection, grinding and operation, and also for adjusting to normal parameters;
- the greasing schemes and the maintenance and repairing instructions for technical equipment;
- the procedures for equipment disposal by retrieving and reusing the components;
- the technology for repairing, refurbishing and reusing the used parts
- the technology for reusing other materials resulted from dismemberment.

These issues are part of the terotechnics and terotechnology domain.

3. THE USE OF TEROTECHNICS AND TEROTECHNOLOGY IN CONSTRUCTIONS

Terotechnics is the multidisciplinary science which deals with the complex of actions done to ensure the operation at nominal parameters and in safe conditions of the technical equipments, passing through the entire cycle from conception to recycling (fig. 4).

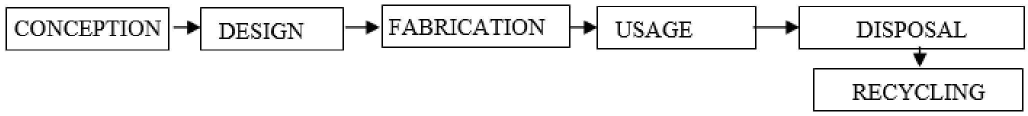

Fig. 4. Technical equipment cycle

Terotechnics deals with the specific matters known as: reliability, maintainability, tribotechnics, ecology and environment, mechanic-energetic design and ergonomy.

Terotechnology deals with applying the organization variants for maintenance, repairing and upgrading the technical equipment and takes into consideration their selection criteria, for reducing the stationary times and intervention costs, by technology preparation in advance and ensuring new or refurbished spare parts (Zafiu, 2005).

Specific regulations are needed furthermore, for getting the desired quality in construction through techical equipment, both regarding its implication in work and by ensuring the normal operation and exploitation conditions on site. The specialists in the field of construction technical equipment agree that their technical certification is the activity which confirms the technical capacity of the equipments to perform quality works and to fulfill the safety requirements, so the work can be done in safe conditions and the technical processes at the required quality level. Surely, the concepts of performance and quality cannot exist without the basic requirements from the regulated domain regarding work security, safety and protection for men, but also in the domain of environmental protection, for construction works where technical equipment has a decisive role (Antohe, 2004).

Therefore, we support the need to further develop some authorized organizations, who can perform the generic activity of ”technical certification”.

The control activity for technical certification of technical equipments in construction takes place according to the regulations in the construction quality field, on three main directions which ensure their operation: user security and protection control, environmental security and protection control, work quality capacity control.

The certification of the technical capacity of construction equipment is done by:

- the conformity certification for new equipment without CE mark;
- technical inspection for the equipment kept in operation after passing the standard lifetime or for second-hand acquisitions.

Current concept improvements of the technical equipment structure lead to constructive solutions which allowed the use of board computers and automatic regulation systems of functional parameters, such as:

- the implementation of sensors, to give information on environment and equipment condition;
- the use of information processing and interpretation resources;
- the introduction of artificial intelligence in equipment lead systems.

This was occasioned by the generalization of hydrostatic actions and was concretized by:

- automatic regulation of work parameters of hydrostatic pumps depending on the work equipment opposition, in order to keep the motor moment constant;
- automatic commanding through the board computer of the work technical parameters, not depending on the machine position;
- the association of some measurement and control devices (MCD) with construction installations, both for the continuous regulation of some work parameters and for the automatic control of work quality;
- the assurance of preventive maintenance through integrated, operational systems which to evaluate continuously the technical condition of the machine.

Taking into consideration the CPP characteristics, the design of technical equipment has to keep in mind, beside the negative effects of the operation environment, a series of constructive particularities:

- the high degree of mobility on site;
- the difficulties in providing the command execution precision;
- the intense interraction between the equipment and environment, to help locating the work areas, etc.;
- the need of superior specialization of operation through intense training;
- the conceiving of the man-machine interference, depending on site specifics;
- the distinction of particularities depending on the work conditions: temperature, dust, humidity, rain, wind, shocks, vibrations.

Therefore, there are three main factors in order to ensure the technical conditions for equipment use:

- the workforce quality – the more advanced are the equipment the more skilled has to be the mechanics, both for operation and for maintenence;
- the processed materials quality – the technical compatibility between the equipment and the processed material properties;
- the work conditions – keeping minimal work conditions for processes, according to the requirements from the equipment use technical instructions.

4. THE ROLE OF TECHNICAL PROJECT IN CONSTRUCTION EXECUTION

The technical project (THP) aims to create the technical-economic documentation for construction execution which will basically solve the following issues (Zafiu et al, 2004):

- the analysis of the technical process and finding mechanization alternatives;
- the selection of the mechanized alternative for the construction-assembly works (C+A), based on the technical-economic indicators and pointing out the backup alternatives;
- the choice / design of the auxiliary devices used;

• the elaboration of technologic plans for work mechanization and the technologic files on basic activities and complex processes;

• the schedule of mechanized execution of construction works considering the resources needed and their technologic usage, but also the schedule optimization in order to fit the technical-economic parameters of the works;

• the elaboration of the requirements regarding work safety, work and environmental protection.

THP will be done in order to give the technical information needed for the general coordination of construction works through project management, quality management and safety, work and environmental protection management.

THP is the main documentation source for the elaboration of procedures from the quality manuals, but also for the other documents needed to implement the construction quality system.

The execution details (ED) are part of the technical project (TP) and represents the documentation given by the designers, needed to clarify constructive details so the construction to fulfill all the parameters according to the project, legislation and construction certification.

Through THP the objective and the nearby constructions can be traced, during work execution. THP has to follow all the TP requirements and the ED regarding the work quality control and, if necessary, to extend by introducing additional controls.

In order to guarantee a safe, quality construction, the THP has to provide activities regarding the work execution surveillance and technical quality control, during the execution process.

THP provides the norms to be followed in work execution, having in mind the following requirements: personnel safety, location safety, execution procedure safety, technical equipment operation safety.

THP will give technical solutions and will make recommendations in order to reduce, during the construction works, the effects on the environment caused by: noise, terrain vibrations, air pollution, surface water pollution, underground water pollution, ground pollution.

In order to supervise the construction process and the execution quality, there will be established:

• the validity of design hypothesis;

• the identification of the differences between real terrain conditions and design conditions;

• the detailed planning of actions in order to establish if the construction works are done according to the THP and to the technical regulations in the field.

The level and quality of the surveillance and monitoring has to be at least the ones in the project, according to the safety parameters and coefficients.

There will be identified the elements which were the base for the project development and were influenced by the surveillance and monitoring activities.

The inspection, control and field and lab tests requested by the technical process surveillance and by monitoring the construction behavior during works must be established together with the THP development, which should include a „Program for the quality insurance of the execution".

The THP development should consider the aspects from the technical certifications, issued by certification organizations, given to certain technical equipment, materials and procedures, which fulfill the norms of certification procedures. The THP is written by the constructor, depending on his technical endowment and the workforce needed. The following aspects are taken into consideration: the ease of work execution, fitting the scheduled costs, respecting the execution schedule, respecting the imposed quality norms. The specialized technical personnel who takes place to THP development should be certified by professional authorities (Ceauşu, 1992). Respecting the technical documentation for execution should be stated clearly in the THP.

5. CONCLUSIONS

The construction quality should have a complex scientific approach, since the implications of low quality are bigger compared to other products.

The construction quality is not only a problem of the constructor, it is a national problem and lately European or worldwide problem. Therefore, the E.U. assigned the European Committee for Standardization to establish norms which to acknowledge the organizations and labs which certify quality in all member states.

The total quality management system targets all the aspects of company activity and states quality as strategic element.

The total quality management strategy is materialized in the integrated effort at all company levels in order to increase the client satisfaction through continuous practical improvements.

The paper presents the quality importance for constructions, the causes of lower quality, the quality cycle and the quality system in construction. At the end there are described the information sources, the methods and technics used in quality planning, insurance and control for construction works.

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ANALYSIS OF GEO-MECHANIC PHENOMENON THAT LED TO THE COLLAPSE OF SETUP ENTRY OF TOP COAL CAVING LONGWALL MINING, FROM PAN.7C, COAL SEAM NO.3, BLOCK IV, LUPENI MINE, ON 10.05.2017

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EUGEN COZMA [2]

Abstract: *This paper refers to the analysis of the causes that led to the collapse of the setup entry of top coal caving longwall mining Pan.7C, Lupeni, and dated 10.05.2017. There is developed the geo-mechanic phenomenon, taking into account the coal deposit tectonics, stress state and blasting workings influence.*

Keywords: *setup entry, top coal caving, longwall mining, hydraulic prop, articulated beam, stress, collapse, roof falling down, blasting*

1. GEOLOGICAL CHARACTERIZATION OF THE COAL SEAM NO.3, BLOCK IV, E.M. LUPENI

Coal seam no. 3 has the highest economical importance of this coal basin and implicitly of the Lupeni mining field. It is located at 20-50m at the limit of Ruppelian - Chattian. The coal seam thickness ranging from 40m, at the north, to 10m, at the Jiu pillar and city Lupeni zones. It consists of several coal bands with clay intercalations.

The roof of the coal seam no.3 is formed by argillaceous and calcareous sandstones, striped, well stacked and blackish sandy clays, riche fossil flora and fauna and with the frequent siderite concretions.

The rocks floor is made of fine and compact sandy blackish clays with sphero-siderite concretions.

Coal seam no.3, with a thickness of 20-24m, is a complex seam consisting of coal bands with an average total thickness of 14.6m, separated by intercalations of clays and sandstones, with an average thickness of 5.4m. Toward the coal seam floor, the intercalations are represented by blackish-brown clays, with carbonaceous and

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bituminous substances, with many slickensides. In the middle of coal seam, the intercalations are formed by gray and micaceous sandstones which usually are a false floor layer. Toward the roof, the intercalations become again argillaceous, with many siderite and calcareous concretions.

In the zone of setup entry of Pan.7C, Bl. IV, coal seam no.3 has a thickness of about 20m and overburden rocks with a thickness of 373m, up to the surface, non-susceptible to rock bursts. Following the laboratory measurements it was found that the roof rocks have low to medium strength, coal has low strength and the faults low shear strength (table no. 1).

Table 1. Average values of the physical, mechanical and elastic properties of the roof rocks and coal seam no. 3, Lupeni mine [18]

Name	$\gamma_a \cdot 10^4$, [N/m^3]	σ_{rc}, [MPa]	σ_{rt}, [MPa]	*C*, [MPa]	φ, [grade]	*E*, [MPa]	ν
Coal seam no.3	1.31	9.5 – 18.0	0.8 – 1.3	1.1 – 2.5	49 – 58	530 – 1,600	0.17
Immediate roof rocks	2.58	44.1	5.6	6.0	50	5,100	0.2
Main roof rocks	2.609	128.0	13.2	20.5	54	5,500	0.12

Notations: γ_a - apparent specific weight; σ_{rc} - compressive strength; σ_{rt} - tensile strength; *C*-cohesion; φ - internal friction angle; *E* - elasticity modulus; ν - Poisson's ratio

2. INFLUENCE OF NEIGHBOURING MINING PANELS ON THE STATE OF STRESS AND STRAIN AROUND THE SETUP ENTRY PANEL 7C

The longwall face with top coal caving is situated on the Coal seam no.3, Block IV, and develops in the Panel 7C with an extension of 155m, along the strike. It mines the first slice of the coal seam no.3 with an average thickness of 10m, from a total thickness of about 20m. The average dip of the longwall face is 14° and the face upward advancement dip is aprox.10^o. The average depth of the setup entry working location, measured from the surface, is 373m (the difference between the surface level of +685.4m and the average level of the setup entry of +312.5m).

The mentioned panel has been initially mined on an extension of about 45m, with a coal face with 97m of length. Then, it was left a barrier pillar with 20m of size, and it was restarted the mining of coal seam by digging a setup entry working of 82.4m of length, the average height of 2.5m and a width of 3.75m.

The preparatory workings of the panel are constituted by the transport entry, with initial length of 140m, located at the upward side of the longwall face, and the ventilation entry, with the length of 160m, located at the bottom of the coal face.

In the vicinity of the panel to be analyzed the following mined panels, which influence the stress and strain state around the top coal caving longwall Pan.7C, are situated:

-the initially mined zone, in the same Panel 7C, with the extension of 45m and separated by a barrier pillar with 20m width by report to the analysed setup entry;

-the Panel 7A, Coal seam no.3, Block VI, near transport gallery, situated approx. 30m away from the transport gallery of Pan.7C, at +325m level; the panel 7A sizes were: 150m following the seam straight, 60m coal face length and 10m mined height of the coal seam;

-the Panel 1C, Coal seam no.3, Block IV, near the ventilation gallery of the Panel 7C, with an extension of 420m, was mined by a longwall face with 100m of length, and the four slices have been mined, with a total thickness of 14m; they are separated by a safety pillar with average width of approx. 30m.

The natural states of stress of the top coal caving longwall face Pan. 7C zone, to an average depth of approx. H = 373m, it can be appreciated to been given by a vertical stress $\sigma_v = \gamma_a \cdot H = 0.026 \cdot 373$ =9.69MPa and a horizontal stress $\sigma_h = \frac{\nu}{1-\nu} \cdot \sigma_v = 0{,}25 \cdot 9.69$ =2.42MPa – where: γ_a is the average apparent specific weight of the roof rocks; ν - average Poisson's ratio of the overburden rocks [8], [17].

Following the voids generated by extracting the coal from the previous panels, the initial state of stress and strain of massive changed dramatically, leading to a stress concentration around the coal face, preparatory and active opening workings. As an immediate consequence, we can observe an intensive convergence of the preparatory workings, closure of the hydraulic props and the influence on the collapse phenomenon from the setup entry Pan.7C.

After a perpendicular direction on the preparatory workings of the panel 7C, the natural stress concentration factor is [15]:

$$k_1 = \frac{l_{ab1}/2 + l_{p1} + l_{ab2} + l_{p2} + l_{ab3}/2 + n \cdot l_g}{l_{p1} + l_{ab2} + l_{p2}} = 1.65$$

where: l_{ab1}= 60m - length of the coal face Pan.7A; l_{ab2}= 79m - length of the coal face Pan.7C; l_{ab3}= 100m - length of the coal face Pan.1C; l_{p1} = 30m - pillar width between Pan.7A / 7C; l_{p2}= 30m - pillar width between Pan.7C / 1C; l_g = 3.5 m - width of a preparatory gallery; n = 4 - number of preparatory galleries.

In *conclusion*, the presence of the adjacent mined panels, corresponding of the panels 7A and 1C led to a supplementary concentration of the stress on the panel 7C and on the neighboring pillars of about 65%: $\sigma_{v1} = 9{,}69 \cdot k_1 \cong 15.6$ MPa; $\sigma_{h1} = 2.42 \cdot k_1 \cong$ 4MPa.

Also, from the practical experience (referred to the speciality literature [3], [7], [8], [9], [17]) it can be seen an additional concentration of stress in the marginal areas, towards the gobs, called abutment pressures (depending on the overburden and the excavation height) of about 80%, respectively a factor of the stress concentration

$k_2 = 1.8$ and a concentration ratio on the preparatory workings walls of approx. 30%, respectively $k_3 = 1.3$. Therefore, it could be estimated some vertical stresses, developed on the pillars limits on the gobs, of about $\sigma_{v2} = \sigma_{v1} \cdot k_2 = 15.6 \cdot 1.8 = 28.08$ MPa and on the preparatory workings walls of $\sigma_{v3} = \sigma_{v1} \cdot k_3 = 15.60 \cdot 1.3 = 20.28$ MPa (Fig.1.a).

The coal seam no. 3 is crossed by several directional faults. In the most important fault area, with a dip of 50.4°, near the transport gallery (tailentry), the stresses have a significant increasing of 3-4 times the value of the stresses σ_{v1} (over 45MPa).

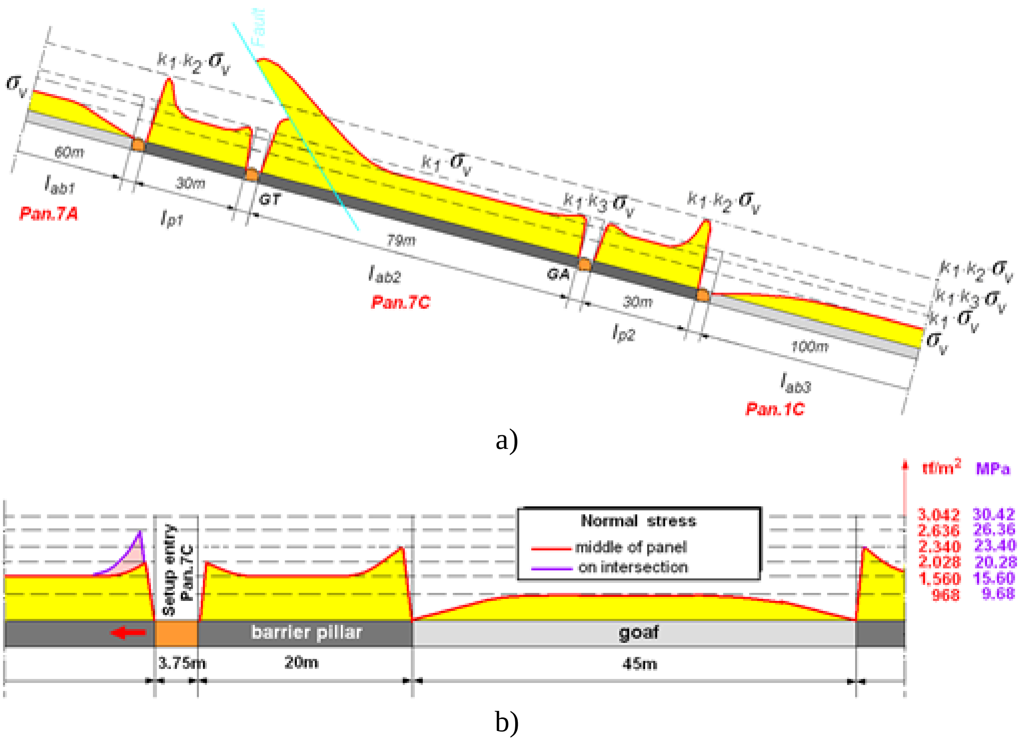

Fig. 1. Normal stress distribution around the setup entry Pan.7C, Coal seam no.3, Block IV [15]: a) cross-cut perpendicular to the preparatory workings; b) cross-cut perpendicular to the setup entry 7C

Analyzing the state of stress following a plane perpendicular to the preparatory workings of the setup entry Pan.7C (fig.1.b), we estimate an increase of the state of stresses σ_{v1} on the setup entry walls, towards the pillar, of about 50% and to the opposite wall, with approx. 30%, respectively 23MPa and 20.28MPa. At the intersections between setup entry and preparatory workings it can talk about an increase of the stresses σ_{v3} with the same percentages, respectively 30.42MPa and 26.64MPa.

3. BLASTING INFLUENCE ON THE MASSIVE STABILITY AROUND THE TOP COAL CAVING SETUP ENTRY

After the integral digging of top coal caving setup entry Coal seam no.3, Block. IV, Pan.7C and it's supporting with 3 articulated beams and 5 hydraulic props (according to the framework project), respectively the mounting of 104 frames/raws, on the length face of 82.4m, it was passed to the start at the first step of top coal caving. These drilling-blasting works were carried out in 11 stages, during 10.02.2017 - 10.04.2017, on the sections of 3.2 meters, with a number of 155 holes and is consuming a total of 77.5kg metanit.

From the speciality literature [1], [2], [5] it is known that the energy of rock blasting may cause a rocks dislocation after the weakness planes, that crossing the rock massif (cleavage planes, cracks, fissures, faults, etc.). It is noted that the massive surrounding the setup entry Pan.7C is passed through a series of faults and the cleavage planes, the stability of which could be affected by the blasting works.

Although, the amount of explosive (metanit) detonated at one time did not exceed the 7.5-8.0 kg, repeated blasting (11 rounds) carried out at a short distance from the collapsed section of the setup entry (starting approx. from the centre of collapsed section, between the columns 40-44, on 10.02.2017 and continuing toward the head entry, up on 04.10.2017) could cause the dislocation of the weakness planes of the massive coal and even the roof rocks (faults strength under 1MPa).

Dislocations after the weakness planes could cause sudden involvement of large masses of rocks in the affected area, which developed important dynamic loads on the setup entry supports.

The setup entry Pan.7C is crossed by two approximately directional faults: one with dip aprox.61.2^o, at a distance of 4m from the tailentry; another one with a dip of 50.4^o, at a distance of cca.20m from tailentry (both inclined in the same direction with the coal seam dip).

Considering that the first fault is located in the intersection zone between the setup entry and transport gallery/tailentry, where the stresses concentration is highest (see fig. 1), rationally, the collapse should to occur after that fault and not by the second, which clearly defines the remaining section of non-collapsed section of the setup entry, by report to the collapsed section. The explanation lies in the fact that the seismic waves propagated from the centre of the 11 explosive charges, detonated systematically at various time intervals and the distance gradually towards the airway/headentry, and have reflected on the surface of this fault, preserving it on the second of the destructive influence of the seismic waves (fig. 2). This phenomenon is further proof of the fact that, in addition to the state of excessive stresses, exerted on Pan.7C, the areas already mined in the neighbouring panels, the effects seismic waves generated by the repeated blastings led to the displacement of coal on this fault and implicitly to the setup entry collapse, produced in the date of 10.05.2017 [15].

The arrangement and orientation of fractures, relative to the coal seam dip, followed by their displacement under the effect of the blasting seismic waves, made possible the development of tangential dynamic loads, oriented from the transport gallery to the ventilation gallery. This led to the destruction of connecting links (pins, forks, stems) between the supporting frames, thereby moving the supporting frames to the ventilation gallery and lying down of the hydraulic props on the setup entry floor, followed by the top coal and roof rocks caving and implicitly the setup entry Pan.7C collapsing.

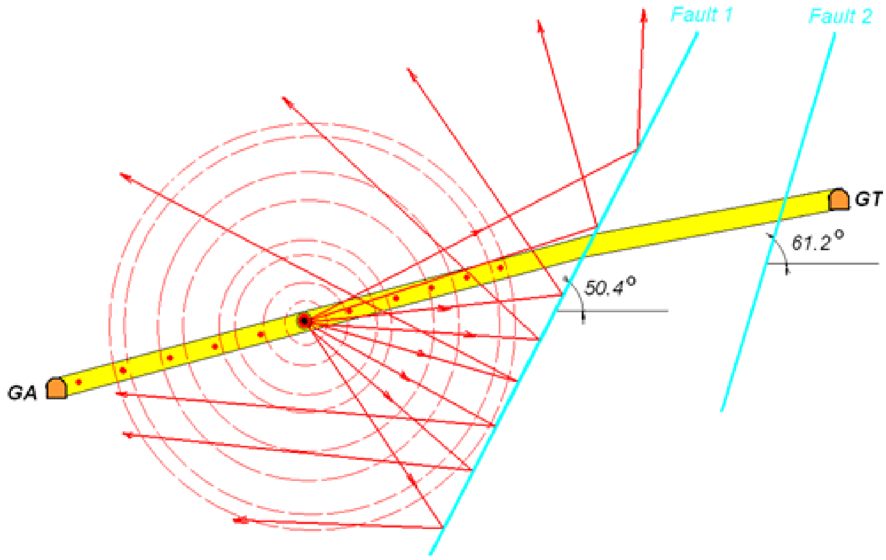

Fig. 2. Effect of the blasting seismic waves generated on the first fault stability [15]
GA, GT – ventilation, transport gallery

4. DETERMINATION OF LOADS DEVELOPED IN THE CEILING SUPPORTING STRUCTURE OF THE SETUP ENTRY PAN.7C, WHEN THE EVENT OCCURRED

After the collapse of the collapse of supports Pan.7C, date of 10.05.2017, were found the following [15]:

-setup entry Panel 7C, Block IV was supported on 3 hydraulic props and 5 articulated - beams, with a total of 104 support raws/frames; the drilling-blasting works carried out over the length of the coal longwall face;

-state of setup entry support, with an overall length of 82.4m, from the transport gallery to the ventilation one was as follows:

-supports of 27 raws (on the 20.8m length of the setup entry), from the raw (1) to (27), has been in operation;

-supports of 40 raws (32m), from the raw (28) to the raw (66), lying on the floor and was caught in the caved coal and rocks roof falling-dawn: 200 of the hydraulic props were fallen on the floor, with the caps oriented toward the airway; 120 articulated beams and 120 spacers fell on the floor;

-supports of the 37 raws (29.6m), from the raw (67) to the raw (104), has been in operation.

Looking at the setup entry situation it can be noted, immediately, that the supporting beams, formed by articulated beams, top coal caving version type GSA-1250S and GSA-570S, would not be able to reach the coal mining face floor than in the conditions in which it would be detached upper raws stable from the unstable ones, by destruction of the coupling elements between the three beams GSA-1250S and the three spacers GSA-570S (which could not have locate as they have been trapped in the caved coal and rocks). The coupling elements loaded to the failure limit are: the pins; the spacers' fork; the beam' stems (Fig.4).

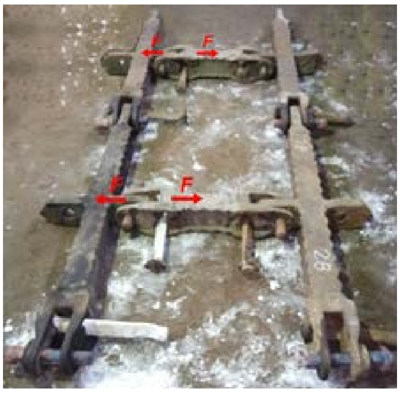

Fig. 3. Coupling between the beams GSA-1250S and the spacers GSA-570S [15]

To quantify the load that led to the destruction of the coupling elements and implicitly the lying down on the floor of the 200 hydraulic props, we will try to analyze the failure stability of the coupling elements previous mentioned. In this regard, it will determine the lowest tangential force P_T (or $3 \cdot F$) developed from the setup entry ceiling which failed the connections between supports, after a certain calculation criterion, from which will be deducted the massive vertical load P which finally led to the setup entry collapse (fig. 4).

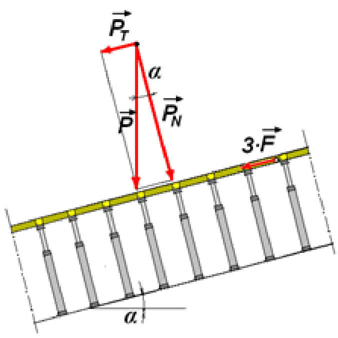

Fig. 4. Loads decomposition of the setup entry ceiling [15]

Further, it will determine the failure load of the pin to shear, crushing and bending and the stem and fork, to tensile (fig. 5) [16], [20].

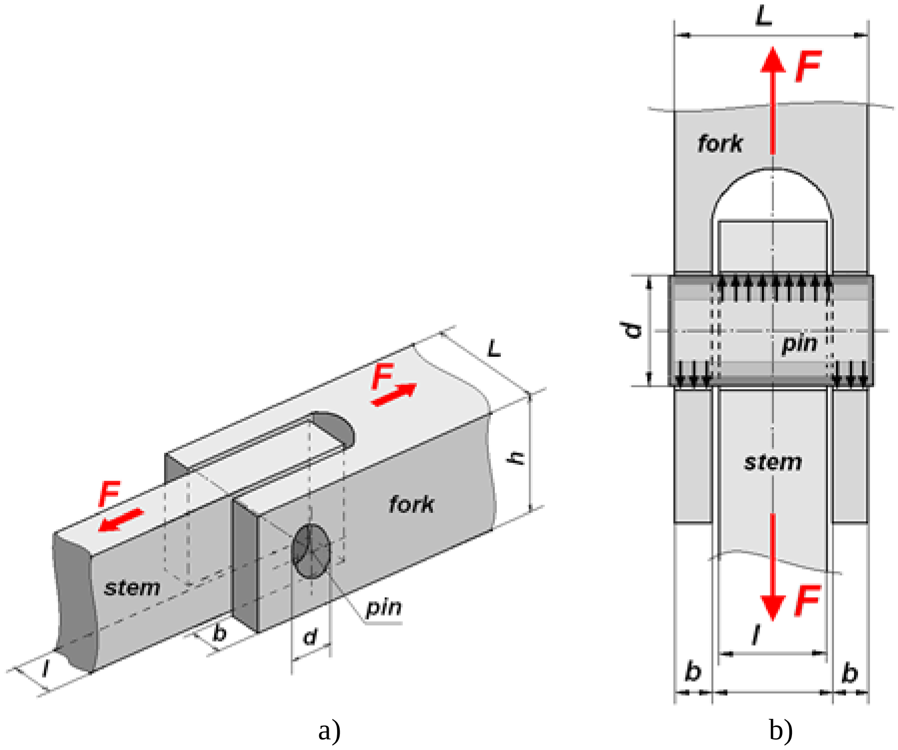

Fig. 5. Connection between the articulated beam GSA-1250S and spacer GSA-570S [15] a) Connection elements assembly: “fork-stem-pin” b) Pin loading

a) The pin loading to the shear, crushing and bending [16], [20]:

-As a consequence of the pin loading to the shear limit, it results that failure force is: F_1 = 1,603.2kN;

-The loading to the crushing limit, between the pin and the stem, causes a failure force: F_{21} = 1,674kN;

-At the crushing limit, between the pin and the fork, results that: F_{22} = 1,674kN;

-Taking into consideration a uniformly distributed load, the loading of pin, calculated at the failure limit, is: F_3 = 187.7kN;

b) The stem and the fork loading to tensile [16], [20]:

-The stem loading to the tensile limit causes: F_4 = 1,435.2kN;

-The fork loading to the tensile limit leads to: F_5 = 1,435.2kN.

Following calculations, it results that P_T tangential load represents the minimum failure force $\min\{F_i\}$ determined by the calculation with i = 5 criteria above, multiplied by the number N of connection between two adjacent rows of articulated beams:

$$P_T = N \cdot \min\{F_i\} = 3 \cdot \min\{F_1, F_{21}, F_{22}, F_3, F_4, F_5\} =$$
$$= 3 \cdot \min\{1{,}603.2; 1{,}674; 1{,}674; 187.7; 1{,}435.2; 1{,}435.2\} = 3 \cdot 187.2 = 561.6\text{kN}$$

In *conclusion*, taking into account the loadings and quality of the steels (pin - OLC 45; fork/stem - OL 52), the pin will break first following the bending loading, then the stem and fork which are loaded by traction.

Where, the vertical load P, corresponding to the tangential force P_T , is the following [15]:

$$P = \frac{P_T}{\sin\alpha} = \frac{561.6}{\sin 14^o} \cong 2{,}321.4\,\text{kN (232.14tf)}$$

Accordingly, the vertical pressure p_v, developed from the roof rocks on the face ceiling is:

$$p_v = \frac{P}{3 \cdot l_g \cdot d_c} = \frac{2{,}321.4}{3 \cdot 1.25 \cdot 0.8} = 773.8\,\text{kN/m}^2\text{ (0.77MPa)}$$

where: l_g is beam length; d_c - the distance between the rows of articulated beams.

Normal pressure p_n, perpendicular to the ceiling of the coal face is:

$$p_n = p_v \cdot \cos\alpha = 773.8 \cdot \cos 14^o = 750.8\,\text{kN/m}^2\text{ (0.75MPa)}$$

The maximum load capacity of the support [4], [6], [13]:

$$p_{\max} = \frac{n_s \cdot P_{\max}}{n_g \cdot l_g \cdot d_c} = \frac{5 \cdot 300}{3 \cdot 1.25 \cdot 0.8} = 500\,\text{kN/m}^2 < p_n = 750.8\text{kN/m}^2\text{ (0.50MPa<0.75MPa)}$$

where: n_s is the number of hydraulic props per raw; n_g - the number of articulated beams per raw; P_{max} - the nominal load capacity of a hydraulic prop, in kN; l_g - the length of a articulated beam, in m; d_c - distance between support raws, in m

Hence, it results that the loading which caused the pins failure by bending is approx. K_s = 1.5 times the maximum load capacity of the support. More specifically, if the hydraulic props did not lie, they would have been destroyed by compression, because of the dynamic overload to which they were subjected.

The energy generated by the ceiling loads could not have dissipated by hydraulic props sliding, due to the inertia of the valves (which are not rapidly discharging).

For a static load developed from the ceiling $p_v = \gamma_a \cdot h_s$ capable of causing the three pins failure, the height h_s of the broken roof rocks can be estimated as:

$$h_s = \frac{p_v}{\gamma_a} = \frac{0.77}{0.02} = 38.5\,\mathrm{m}$$

Since the collapse height of the roof rocks h_s [10], [11], [12], [19], previous calculated, is greater than $h_s \cong 38\,\mathrm{m} >> (6 \div 8) \cdot m_{\exp l} = (6 \div 8) \cdot 2.5 = 15 \div 20\,\mathrm{m}$, then the load on the coal face support, which led to a collapse in setup entry Pan.7C, on 10.05.2017, have not been a static load p_v, but a dynamic load p_{vd}= 773.08kN/m^2 (0.77MPa) or $p_{vd} = k_d \cdot \gamma_a \cdot h_{sd}$.

Considering the maximum height equivalent to the dynamic collapse as the h_{sd}=15$\div$20m, the coefficient of dynamic amplification is:

$$k_d = \frac{p_{vd}}{\gamma_a \cdot h_{sd}} = \frac{0.77}{0.02 \cdot (15 \div 20)} \cong 1.9 \div 2.6$$

where: k_d is the dynamic amplification coefficient of the load, developed by the caved/falling down roof rocks.

5. DESCRIPTION OF GEO-MECHANIC DYNAMICS OF THE PHENOMENON OF TOP COAL CAVING SETUP ENTRY PAN.7C, BLOCK IV, COAL SEAM 3, PRODUCED ON 10.05.2017

The top coal caving setup entry Pan.7C was carried out in the period 07.08.2017-02.10.2017, in accordance with the supporting schema of the setup entry (individual hydraulic support, formed by hydraulic props SVJ 250 and ATLAS S ”0”1-250 and articulated beams GSA-1250S and GSA-570S). Thus, on the length of the 82.4m was operated 104 frames (raws), formed by 3 articulated beams and 5 props, for a total of 520 props, 312 articulated beams and 312 articulated spacers (fig. 6).

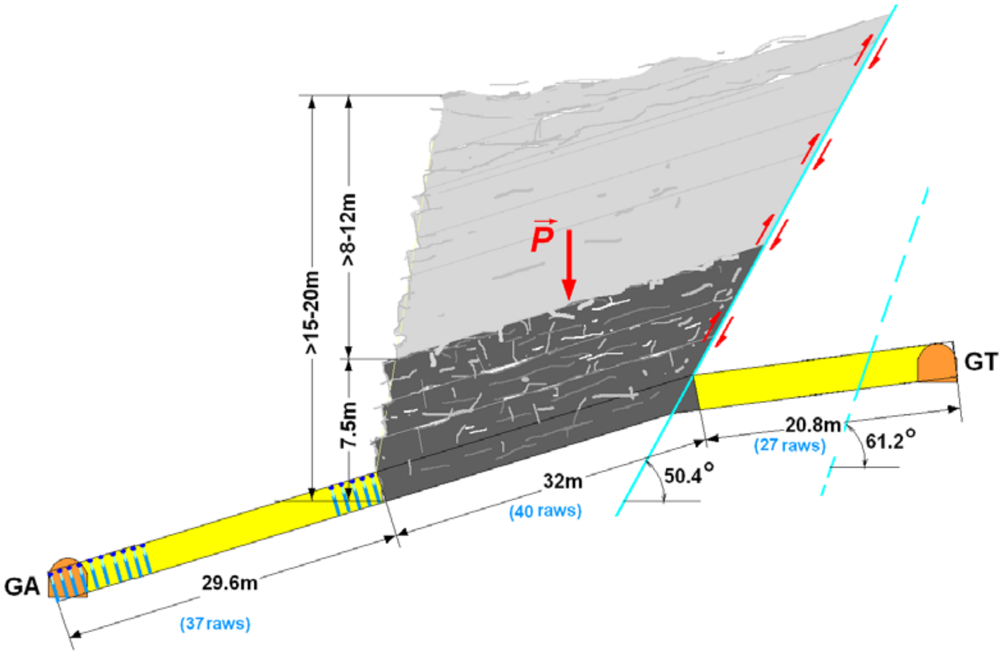

Fig.6. Collapse of the setup entry Pan.7C, Coal Seam no.3, Block IV, E.M.Lupeni, produced on 05.10.2017 [15]

After the supporting the entire length of the setup entry, for to form the dip plane at the barrier pillar limit, necessary to start the mining process, beginning at 02.10.2017 and continued until 12.04.2017, it was carried out drilling-blasting operations. These operations was carried out in 11 rounds, on sections of 3.2 m, from the raws 40-44, located at approx. 30m from the transport gallery and was finalized at the raws 96-100, at the limit of the ventilation gallery (airentry). The quantity of explosive (metanit) detonated at one time did not exceed the 7.5-8.0kg. According to the work permit and the blasting order, it was detonated 77.5 kg of explosive (metanit), arranged in a total of 155 holes.

Multiple blasting in 11 rounds, made from the collapsed section of the setup entry (to about 35 of the upstream wall of the transport gallery) led to the weakening of the first fault plane, with a dip of 50.4°, which intersect the setup entry (resistance shear strength of the fault is naturally very low, under 1MPa) [1], [2], [4].

Displacement of the coal seam on the fault plan, led to a slippage of a coal and rocks column, of more than 15m height, which a dynamic pressure has generated on the supports of approx. 77.38 tf /m^2 (773.8 kN/m^2 or 0.77MPa), greater than 50% than the load capacity of the supports, which is approx. 50tf/m^2 (500kN/m^2 or 0.50MPa). These overloads determined the failure of the pins, interconnected between the rows of the beams, loaded by the certain forces of approx. 187.2kN/pin (18.77 tf /pin), and followed by lying down on the floor of a number of 40 raws, respectively 120 articulated beams and 200 hydraulic props. The fact that all the props were flattened towards the airway, demonstrates that the first time were yielded the pins, and were flattened in turn 40 supporting raws, starting from upstream to downstream. Destruction of the support elements, inevitably led to a top coal caving, on a height of 7.5 m, followed by roof rocks caving on the 8-12m of height, along a coal face section with a length of approx. 32m, from the fault with a dip of 50.4°, to the airway [15].

After the roof rocks falling down produced in the setup entry Pan.7C, Coal seam no.3, Bl. IV, dated 10.05.2017, the support state, from the transport gallery to the ventilation one, was the following: the support from the 27 raws (on the length of 20.8m), from the raw (1) to (27), has been in operation; the support raws 40 (on the length of 32m), from the raw (28)- at the limit the fault with a dip 50,4° – the raw (66) has been lying on the working floor and blocked in the caved rocks (200 hydraulic props and articulated beams 120 were fallen on the setup entry floor, and the props were oriented to the airway); the support of 37 raws (on 29.6m), from the raw (67) to raw (104), has been in operation [15].

6. CONCLUSION

After analyzing of the data regarding to the collapse produced in setup entry Pan.7C, Coal Seam 3, Block IV, dated 05.10.2017, it was found that the factors that led to the geo-mechanic phenomenon were: excessive concentration of stress on the panel 7C; the presence of the directional faults in the panel 7C; low strength of the coal and the fault planes; blasting operations influence on the stability of the fault.

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ANALYSIS OF THE METHODS OF EXPLOITATION APPLIED TO ROMANIAN SALT MINES

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Abstract: Salt is a vital food that has begun to be consumed since the Neolithic period. The history of salt is tumultuous and involves, among other things, the liberation of a people from foreign occupation. Man began to consume salt since the Neolithic period, when he began to diversify his diet and eat vegetal products. Man learned to use salt and became dependent on it probably in the Neolithic, when the transition has been made from an exclusively carnivorous diet to a diet with vegetable products. In 2018, in Romania, three methods of extraction of dried salt are applied, namely: i) method of operation in small rooms and square bunk pillars; ii) method of operation with small rooms and square pillars; iii) small room method and rectangular bunk pillars.

Keywords: *exploitation, method, salt*

1. INTRODUCTION

Nowadays, in Romania are 6 underground salt mines in operation, belonging to teh National Salt Society located in Bucharest. The 6 salt mines presented in Fig. 1 are: Cacica, Ocna Dej, Praid, Slanica Prahova, Ramnicu Valcea and Tg. Ocna. Besides these, salt is also mined with the humid method in Ocna Mures, Tg. Ocna, Cacica and Ocnele Mari (Tamas et al., 2015).

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Fig. 1. Romanian salt mines in operation

Three hypotheses have been drawn up concerning the origins of salt:

- The first one admits that salt dissolved within marine waters and the one from the earth's bark originates from the primordial atmosphere of our planet.
- The second one states that salt was generated by substances released from volcanic eruptions.
- The third admits that salt originates from substances from decomposing miners from the earth's bark.

Some authors state that marine salts started to deposit in a system of lagoons of various dimensions and low depths, in hot climate, slow subsidence of the lagoons bottoms and the presence of a system of large barriers. Small and intermittent lagoons which retained from marine waters calcium and magnesium carbonates, which deposited as dolomites, into the large Transylvanian lagoon (represented by Transylvania and Maramures basins), waters full of sodium chloride and potassium and magnesium salts deposited as salt by cooling down (Fig. 2).

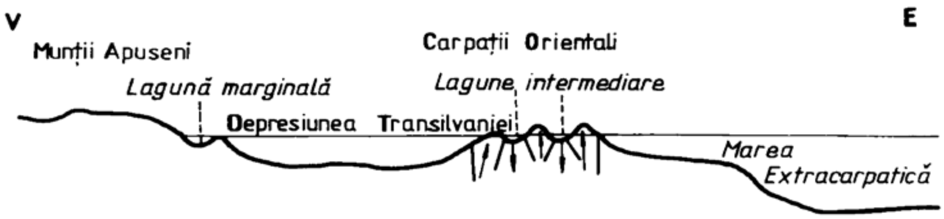


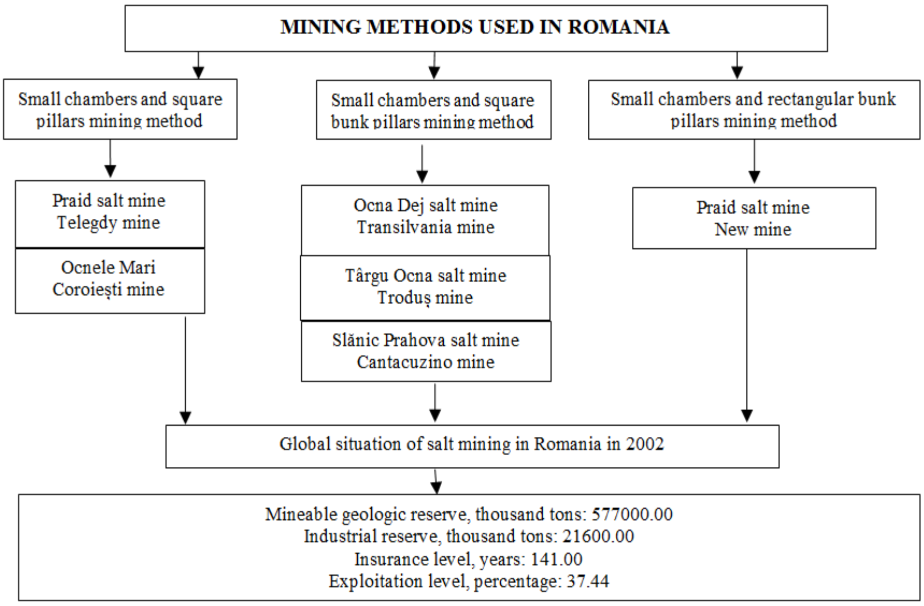
Fig. 2. Configuration of intermediate lagoons

2. SALT MINING METHODS. GENERALITIES.

In 2017, in Romania were applied only three salt mining methods, namely (Table 1):

- Small chambers and square bunk pillars mining method;
- Small chambers and square pillars mining method;
- Small chambers and rectangular bunk pillars mining method.

Table 1. Mining methods used in Romania



2.1. Small chambers and square pillars mining method

The method consists of excavating-blasting of chambers, between which are abandoned paralellipipedic pillars with square base. The exploitation direction is in advance (Fodor, 2015). The chamber-pillar system forms a well-established operational system, the chamber ensuring the space required for extracting the raw material and the pillar the stability of the salt massif. This method involves supporting the roofs of the exploitation chambers and the square pillars, but do not exclude this support when there occur instability phenomena (exfoliation, fissures of roofs and pillar etc.)

In the absence of these phenomena, the rock mass from the roof and pillars has to be maintained in balance, by a proper sizing of the mine's resistance elements, so that the salt between the pillars and roofs to unjustifiably increase operating losses.

Dimensions of the chamber-pillar are gap correlated for 30 m. The gap is the distance between the central vertical axis of two neighbouring chambers, separated by a pillar.

The exploitation method with small chambers and square pillars used in most salt mines has a series of advantages (Chiuzan, 2018; Oprina, 2015):

- The use of machinery is light, taking into account the gauge of the chamber;
- There may be opened a larger number of active work faces located at the same horizon;
- The ventilation network is diminished a lot, not being required special works for each chamber;
- There can be easily avoided waste or low-quality salt areas from the deposit (Leba et al., 2014).

Fig. 3 shows a horizontal section through an exploitation system, where (lp) stands for the width of the pillar, (lc) for the width of the chamber, (e) for the gap. The exploitation coefficient is depending on the gap: inversely proportional with the dimension of the pillars, directly proportional with the dimension of the chambers. Fig. 4 presents the chamber-bunk rectangular pillar system, where g-thickness of the roof, h-height of the chamber, l-width of the chamber, f-pillar.

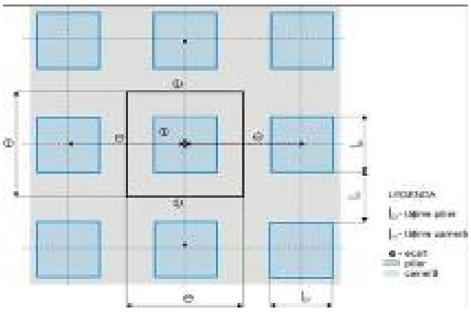


Fig. 3. Horizontal section

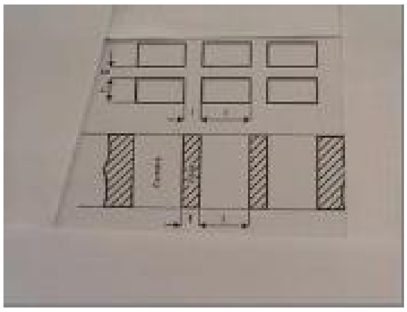


Fig. 4. Horizontal section through the chamber-rectangular pillar system

2.2. Small chambers and rectangular pillars mining method

This method differs from the one presented before only by the shape (rectangular in section) and dimension of the pillars and chambers. Horizontal and vertical gap is larger than for the previous method. This mining method consists in the excavation in the salt massif of chambers of 20 m width and 8-12 m height, separated by rectangular shaped salt pillars (Covaci et al., 1999). These pillars shall take the load of covering rocks, ensuring the stability of the excavation and of the surface. The mining method does not involve the support of chamber roofs and abandoned pillars, but does not exclude it when instability phenomena occur. The exploitation method is developed by MINESA - I.C.P.M. Cluj and it is exclusively used in Praid salt mine – new sector (lower horizons) and is characterised by the following (ICPM Cluj projects, 1986-2014; Popa et al., 1993):

- Roof (pillar) of the salt deposit has a minimum of 30 m thickness;
- Floor pillar of the salt deposit has a minimum of 25 m thickness;

- Marginal pillars for the new sector of Praid salt mine shall have a thickness of 30 m min.;
- Pillars (roofs) between horizons have a min. 8m thickness;
- Pillars between chambers are prisms with width of 20m, length of 40-100m and height of 8-12 m;
- Exploitation chambers with straight roof, width of 20m, height of 8-12 m and length of 20-300m.

Work procedure is the following:

- There is performed the main ventilation gallery (Cioclea et. al, 2015; Cioclea et al., 2014), of 6sqm, connected to the ventilation rising;
- Using the URAL-33 cutter (Fig. 5) is cut a channel in the floor, having 1.8m in depth.
- Workface is perforated using RADA-TELEMAC or SECOMA perforation installation (Fig. 6.);
- Perforated boreholes are loaded with explosive;
- Workface is blasted in two steps (240mp or 200mp);
- Workface is ventilated for 1 - 2 hours;

Roof and walls of the chamber are lined of the freshly blasted slice using the HAULOTTE nacelle (Fig. 7) and the previous slices are verified;

Fig. 5. URAL-33 cutter

Fig. 6. SECOMA perforation installation

Fig. 7. HAULOTTE nacelle

Fig. 8. CASE front loader

- Resulting oversized rocks are broken with hammers or by blasting;
- Resulting salt is loaded using the front loader type STALOWA VOLA/ JCB/ CASE (Fig. 8) into 10t AUSA type dumpers (Fig. 9);

Fig. 9. AUSA dumper

Fig. 10. Rolling collector equipped with grill, mesh size 0.40 X 0.40 m

Salt is transported to the rolling collector equipped with grill, mesh size 0,40 x 0,40m (Fig. 10.) through which it is discharged and transported to the surface;

For ensuring the continuity of the extraction process, the exploitation activity is performed concurrently in at least 3 exploitation chambers, in each one being performed a distinct work phase, according to the methodology described before.

Quantity of salt resulting from a cycle is:

20m x 12 m x 1.8 m x 2.16 (t/mc, spec. weight) = 933.12 tons

20m x 10 m x 1.8 m x 2.16 (t/mc, spec. weight) = 777.60 tons.

2.3. Small chambers and abandoned square pillars, with straight roof mining method

The exploitation method is in compliance with the framework project developed by MINESA - I.C.P.M. Cluj and ahs the following characteristics:

- Roof (pillar) of the salt deposit has a minimum of 30 m thickness;
- Floor pillar of the salt deposit has a minimum of 10 m thickness;
- Marginal pillars range depending in the exploitation depth, from 22m (for h=80-120 m) to 29m (for h=280-400m);
- Pillars (roofs) between horizons have a min. 8m thickness for a depth of 80-100m and 10m for 280m depth.
- Pillars between chambers are prisms with square base (10-18m), 8m height, the dimensions of the base increasing once with the exploitation depth
- Exploitation chambers have a straight roof, width of 12-16m, height of 8 m and length of 20-300m, depending on the size of the exploitation field;
- Work technology is the following:
- Using the cutter is performed a channel having 1.8m in depth into the floor;
- Workface is perforated (128m) with RIPAMONTI EX-180 perforation installation, mounted on a CATERPILLAR 312 C, executing a number of 185 of blasting holes (40mm diameter);
- Boreholes are loaded with explosive, which is initiated using electrical detonators with ms delay.
- Workface is blasted in single step;
- Workface is ventilated for 1-2 h for exhausting blasting gases;

- Roof and walls of the chamber are lined of the freshly blasted slice and the previous slices are verified;
- Resulting oversized rocks are broken with hammers;

Resulting salt is loaded using the front loader type LIEBHERR 541 into dumpers and is directly transported to the processing installation;

Quantity of salt resulting from a cycle is:

16m x 8 m x 1.8 m x 2.16 (t/mc, spec. weight) = 497.66 tons

2.4. Proposed mining method with small chambers and square pillars and shearer cutting

This mining method proposed to be applied is with small directional chambers and square pillars, with straight roof, with descending mining, cutting with the point-driven shearer (Pasculescu et. al, 2015a, and Pasculescu et al., 2015b), loading into mining dumpers with the shearer, auto transportation to the surface.

Chambers and mined integrally from a single positioning of the shearer, into a 5m height and 8m width slice.

The main phases of salt extraction are:

- Performing the directional ventilation gallery (Suvar et. al, 2014; Suvar et. al., 2012) (approx. 1.6-2.0 km on w wing of the deposit) to the margin of the horizon's exploitation field, at the limit of the pillar and putting the ventilation under the mine's general depression;
- Performing the cross-sectional preparation gallery for the exploitation panel to the perimeter limit and putting it under the general depression;
- Cutting salt form opening and preparation works is performed using the point-driven shearer and it is loaded with the shearer in mining dumpers;
- After cutting and exhausting salt from the galleries and/or chambers, roofs are lined so that not to remain any unstable surfaces;
- All digging/cutting works shall be executed under the control of the deposit, the identification/determination of perimeter pillars limit.

Advantages of this mining method are the following:

- Easy performance of the mining exploitation structure, as well as easy leading and monitoring mining works;
- Early identification of solutions required by changes occurred within the deposit during the works;
- Ensuring the control and protection of the deposit, of the performed mining works;
- Easy control of the mine structure;
- Reducing to minimum the possibility of execution mistakes, knowing and respecting the coaxial character of the pillars from the chambers and the crossing of protection pillars;
- By removing blasting, disappear faults occurring within the salt massif.

The point-driven shearer has cutting ends rotating transversally. The cutting arm pivots horizontally over the workface. Once the cutting heads penetrate the workface, the cutting depth is set (Pasculescu et al., 2012; Pasculescu et al., 2014).

Before every horizontal cutting, the cutting head is set up for the cutting thickness, penetrating the front over an additional depth. The cutting depth and thickness are determined depending on the physical and mechanical characteristics of the salt.

Workface penetration is carried out by adjusting the arm or movement of the shearer, while the cutting arm pivots horizontally.

The loading mass, during cutting, has to be located on the floor in order to load the salt while the shearer advances. After the initial penetration of the workface, by the movement of the arm is cut a channel on the floor over the entire cutting length and the cutting thickness is set and the arm is pivoted horizontally.

This new salt mining method by cutting with the shearer is successfully used in a series of European mines, such as: Spain-Iberpotadh (potassium mine), Poland Polkowice-Sieroszewice, Bulgaria etc.

3. CONCLUSIONS

Currently, in Romania and used three underground salt mining methods, namely:

- Small chambers and square bunk pillars mining method;
- Small chambers and square pillars mining method;
- Small chambers and rectangular bunk pillars mining method.

Praid salt mine applies two mining methods, namely:

- Small chambers and square pillars mining method. This mining method is used in Telegdy sector.
- Small chambers and rectangular bunk pillars mining method. This method is used in the New Mine sector.

Using the shearer for mining salt is proper for deep mining, and would substantially improve the mining climate, also the physical productivity, and the biggest advantage would be the almost complete removal of the seismic effect in the pillars.

Besides underground salt mining, salt is also exploited using the humid method in Ocna Mures, Tg. Ocna, Cacica and Ocnele Mari.

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LOADS ESTIMATION IN BLOCK CAVING MINING

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Abstract: Block caving method of mining requires more development work before the start of ore production than most other mining methods. This mining method implies to have high investment costs and these mining methods are quite inflexible. Initiating and sustaining the cave govern the early productivity and economics of the operation. The paper presents both the theory for loads estimation and results for Monte Carlo simulations for a block caving mine, taking into account the following variables: hydraulic radius of the cave; bulk density; horizontal-to-vertical stress ratio; friction angle at the cave walls.

Keywords: *mining, block caving, Monte Carlo simulation, hydraulic radius*

1. INTRODUCTION

The stability of the extraction level excavations is critical to the efficient extraction of the ore from caving mines. Several factors have the potential to influence the levels of stress induced in the extraction level excavation, of which significant is the vertical stress due to cave loading.

Estimation of the vertical stresses/ loads acting on the extraction level in block caving mining is paramount for the optimisation of tunnel lining/ support at the Extraction Level (EL). The limit equilibrium solution proposed by Loren Lorig is employed to estimate the average vertical stress at the cave base. Model inputs are derived from experience, theory and the results of numerical and physical experiments.

Monte Carlo simulations are used to obtain stress estimates at the cave base/ extraction level, due to the high level of uncertainty in evaluating input parameters.

In order to derive loadings on tunnels located at the Extraction Level, we should estimate stresses generated during the block cave mining processes at the base of the drawbell/ drawpoint. These loads are used subsequently into the stress path to design the lining/ support of the tunnels located at Extraction Level.

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2. RELATION BETWEEN CAVED COLUMN HEIGHT AND VERTICAL STRESS AT THE CAVE BASE

Loren Lorig derived a formula for the quantitative estimation of transmitted vertical stress at the base of a block cave, for the plane strain condition using limit equilibrium analyses.

A fundamental assumption inherent in the analyses is that the caved material is drawn uniformly, resulting in a relatively uniform vertical stress acting on the base.

It is important to note that a uniform draw is seldom achieved in practice. The problem to be analysed is represented in the Fig. 1, and the specific goal was to quantitatively derive the relationship between the base pressure, p, and the geometry of the prism.

Using the limit equilibrium methods for the three-dimensional case, Lorig derived the following formula:

$$\frac{p}{\gamma H} = \frac{1}{\frac{H}{R_H} K_p tan\emptyset}\left(1 - e^{\frac{H}{R_H} K_p tan\emptyset}\right) \quad (1)$$

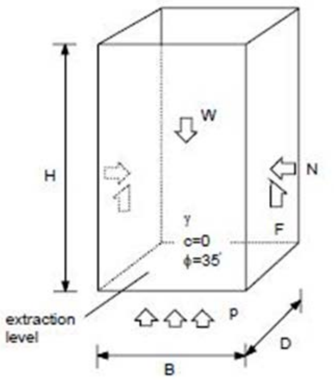


Fig. 1. Lorig representation of the cave

3. ESTIMATION OF VERTICAL CAVE LOADS ON EXTRACTION LEVEL USING PIERCE'S MODEL

The limit equilibrium solution adopted by Lorig is based on the bin theory of Janssen (1895), where the vertical stress – at a depth z, below the free surface of a bin is given by:

$$\sigma_v = \frac{R_h * \rho_b * g}{\tan \varphi_w * k}\left(1 - e^{\frac{-k * \tan \varphi_w * z}{R_h}}\right) \quad (2)$$

where:

- R_h – is the bin hydraulic radius (equal to the area divided by the perimeter);
- ρ_b – is the bulk density;
- g – is the gravitational constant;
- k – is the ratio of horizontal-to-vertical stress;
- φ_w – is the friction angle at the bin wall.

The friction angle of caved rock varies within a cave due to variability in bulk porosity, stress UCS of the rock fragments. Barton and Kjaernsly (1981) derived an empirical rockfill shear strength criterion:

$$\varphi = \varphi_b + R * log\left(\frac{RBS}{\sigma_n}\right) \quad (3)$$

in which:

- φ_b – is the basic friction angle, estimated from shear or tilt tests;
- R – is the equivalent roughness of the caved rock – estimated from porosity and fragment roundedness/ smoothness;
- RBS – is the rock block strength;
- σ_n – is the normal stress – in this case, the horizontal stress at the cave perimeter.

The initial formulation of Barton & Kjaernsli shows that Shear Strength (S) was used instead of RBS. Their dependency is presented in (4):

$$\varphi' = R \cdot log\left(\frac{S}{\sigma_n'}\right) + \varphi_b \quad (4)$$

Relationship between horizontal stress, friction angle and the equivalent roughness is presented in Fig. 2.

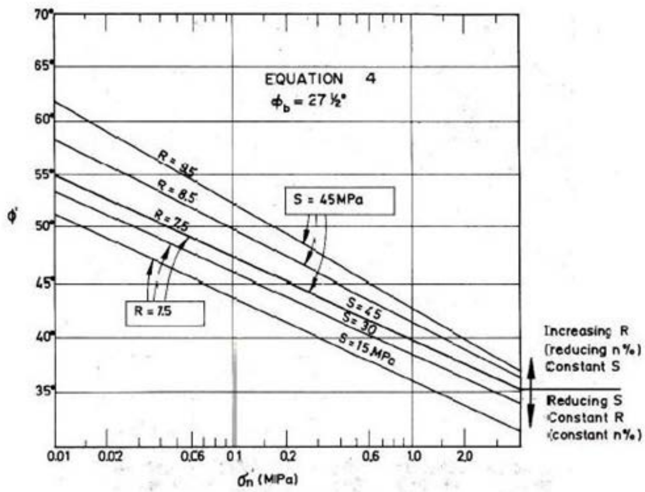


Fig. 2. Horizontal stress as a function of friction angle

4. ACTUAL MODELLING USING @RISK – MONTE CARLO SIMULATIONS

In order to perform a probabilistic analysis of the above-presented model of the stresses/ loads at the Excavation Level, Monte Carlo simulations have been performed, using @RISK addon for Excel for Windows.

Input parameters used for simulations are presented in Table 1 – we have used Normal Distributions for the majority of parameters:

Table 1. Parameters and their normal distributions used in simulations

No.	Parameter	Distribution	Variance
1.	Hydraulic Radius, m	RiskNormal (120,10)	120±30
2.	Bulk Density, kg/ m3	RiskNormal (3200,233.3)	3200±700
3.	Gravitational Constant, m/s2	9.81	
4.	Basic Friction Angle, degrees	RiskNormal (30,1.66)	30±5
5.	H-to-V Stress Ratio	RiskNormal (0.5,0.03)	0.5±0.1
6.	Depth from Surface, m	RiskUniform (0,600)	0÷600
7.	Draw Factor	RiskUniform (2,3)	2÷3
8.	Rock Block Strength, MPa	RiskNormal (35,5)	35±15
9.	Equivalent Roughness	RiskNormal (4,1)	4±3

and input parameters for Uniform Distributions (for Model Rev. 6), are shown in Table 2.

Table 2. Parameters and their uniform distributions used in simulations

No.	Parameter	Distribution
1.	Hydraulic Radius, m	120
2.	Bulk Density, kg/ m3	RiskUniform (2550, 3050, RiskStatic (3200))
3.	Gravitational Constant, m/s2	9.81
4.	Basic Friction Angle, degrees	RiskUniform (20, 35, RiskStatic (30))
5.	H-to-V Stress Ratio	RiskUniform (0.3, 0.6, RiskStatic (0.5))
6.	Depth from Surface, m	RiskUniform (0,600)
7.	Draw Factor	RiskUniform (2,3)
8.	Rock Block Strength, MPa	RiskUniform (20, 100, RiskStatic (35))
9.	Equivalent Roughness	RiskUniform(1, 7, RiskStatic (4))

The following models were run, considering various assumptions as detailed below:

- Rev. 1 – only vertical stresses based on Lorig formula;
- Rev .2 – Pierce’s approach with R=1 and DF=3;
- Rev. 3 – R – Normal Distribution and DF=3;
- Rev. 4 – DF – Uniform Distribution; Full simulation using parameters as in Table 1;
- Rev. 5 – as per Rev.4 with R=0;
- Rev. 6 - Full simulation using parameters as in Table 2.

Simulation results are contained in each Excel file generated and a summary for Rev.4, Rev.5 and Rev.6 is presented below (Fig. 3 – Fig. 9):

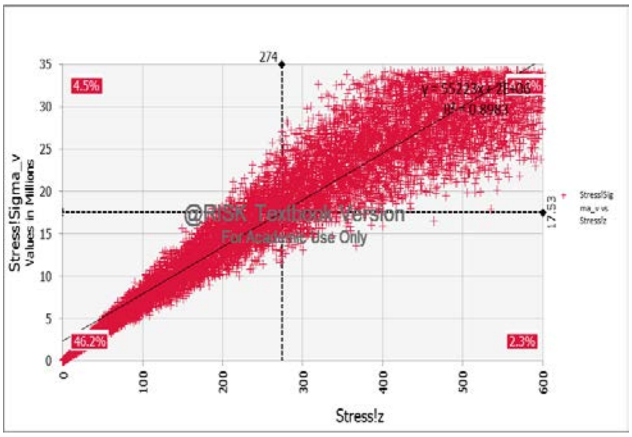


Fig. 3. Realizations for 90% confidence for model rev.4

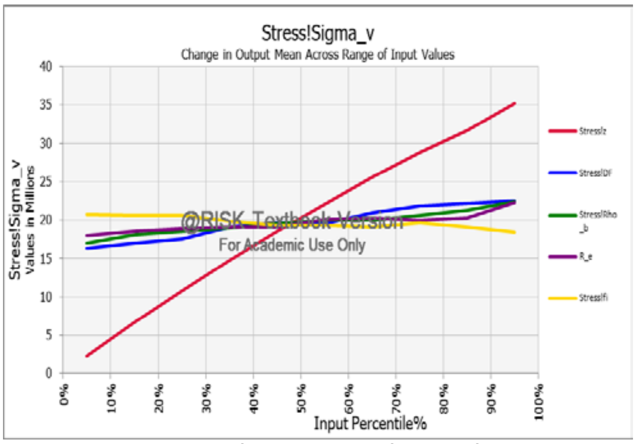
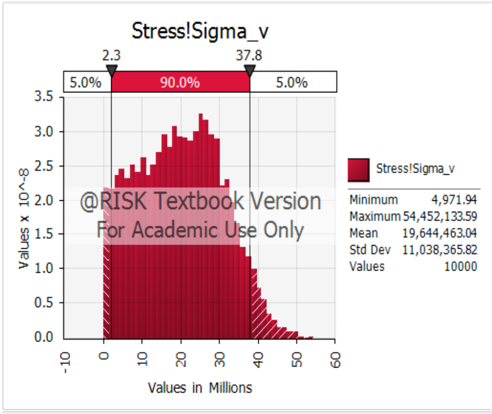


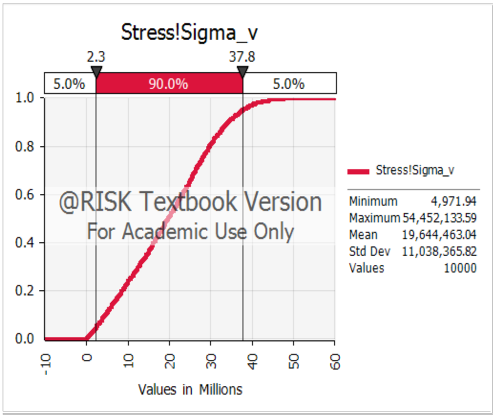
Fig. 4. Spider graph of parameter influence for model rev.4

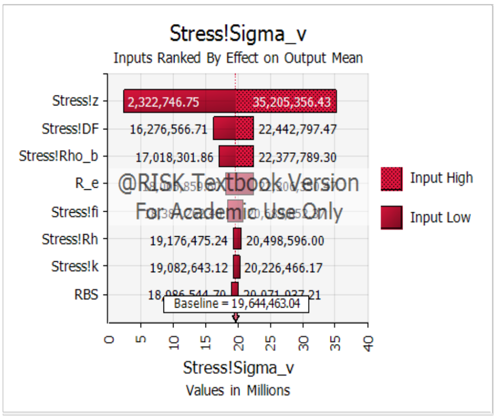
@RISK Output Report for Stress!Sigma_v D15

Performed By: Madear, Gelu

Date: 12 July 2018 15:15:48







Simulation Summary Information	
Workbook Name	Caving Loads - MC_Rev4.x
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	8
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	12/07/2018 13:15
Simulation Duration	00:00:33
Random # Generator	Mersenne Twister
Random Seed	1208086226

Summary Statistics for Stress!Sigma_v			
Statistics		**Percentile**	
Minimum	4971.939921	5%	2317419.6
Maximum	54452133.59	10%	4478827
Mean	19644463.04	15%	6579271.8
Std Dev	11038365.82	20%	8557154.4
Variance	1.21846E+14	25%	10519172
Skewness	0.12977147	30%	12623668
Kurtosis	2.210098559	35%	14505707
Median	19646448.05	40%	16230539
Mode	21239397.28	45%	18032649
Left X	2317419.608	50%	19646448
Left P	5%	55%	21381628
Right X	37781887.18	60%	23128013
Right P	95%	65%	24754220
Diff X	35464467.57	70%	26296683
Diff P	90%	75%	27982335
#Errors	0	80%	29673755
Filter Min	0%	85%	31772196
Filter Max	100%	90%	34227493
#Filtered	0	95%	37781887

Change in Output Statistic for Stress!Sigma_v			
Rank	**Name**	**Lower**	**Upper**
1	Stress!z	2322746.7	35205356
2	Stress!DF	16276567	22442797
3	Stress!Rho_b	17018302	22377789
4	R_e	18005860	22306350
5	Stress!fi	18387262	20689852
6	Stress!Rh	19176475	20498596
7	Stress!k	19082643	20226466
8	RBS	18986545	20071937

Fig. 5. Results for Rev. 4 simulation inclusive of table statistics

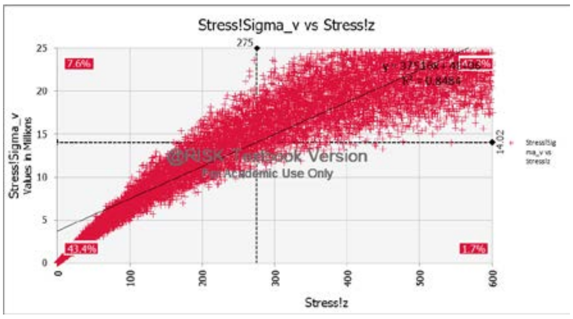


Fig. 6. Realizations for 90% confidence for model rev.5

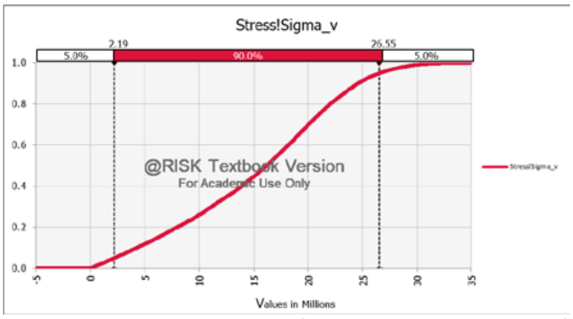


Fig. 7. Cumulative Distribution Function for caving loads (stress) for model rev.5

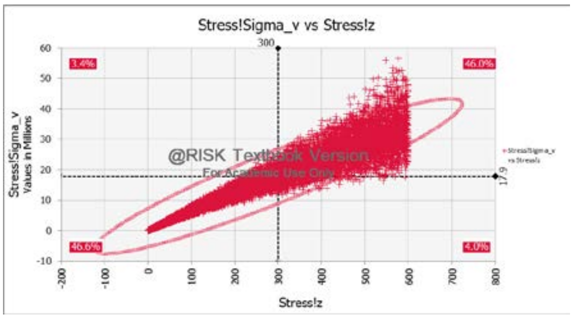


Fig. 8. Realizations within 95% ellipse confidence for caving loads (stress) for model rev.6

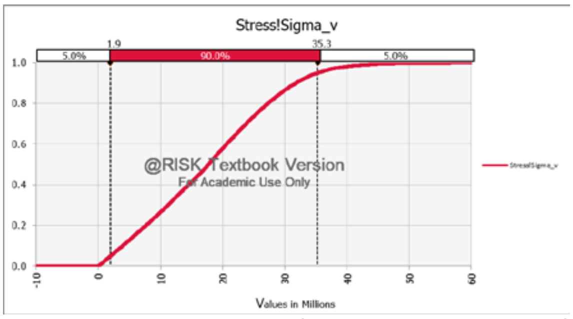


Fig. 9. Cumulative Distribution Function for caving loads (stress) for model rev.6

Fig. 3, Fig. 6 and Fig. 8 show the variation of stresses with depth at the Excavation Level.

5. CONCLUSIONS

- The vertical stresses on the extraction level are likely to vary from the average stress estimated by Lorig formula due to the redistributing effects of the draw;
- Physical experiments demonstrated that under less ideal draw conditions, the stress could be as much as 3 times the average vertical load;
- Incorporating a Draw Factor of 2-3 into Monte Carlo simulations, we obtain an estimate of the maximum cave load on the major apexes at various depths;
- If the footprint were consistently drawn over a smaller hydraulic radius (less than the total footprint H*Rh), these stresses would be lower due to enhanced arching of stresses into the surrounding stagnant undrawn material.

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Palisade, @RISK for Risk Analysis, www.palisade.com.

Scientific Reviewer:
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CHARACTERIZATION AND CLASSIFICATION OF ANDESITES OF CRISCIOR AND ALBINI FROM SOUTHERN APUSENI MOUNTAINS, FOR CAPITALIZATION

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CSABA LORINȚ [3]
ADRIAN FLOREA [4]

Abstract: The use of rocks in construction is governed by standards that require a series of chemical criteria, mineralogical-petrographic and physical-mechanical that they must meet. The execution of various works is permitted only if they fall within certain quality criteria. In this context, the geo-mechanical properties were determined for Criscior and Albini andesites, which were compared with the conditions of admissibility imposed by current standards, for use in different areas. To get a more detailed view of geo-mechanical properties of the Criscior and Albini andesites it was required a classification based on three criteria: chemical, geological and geo-mechanical. The chemical criterion of intact rock classification considers the content of SiO_2 and alkali-aggregate reaction. From the geological point of view, there were chosen for classification purposes those features that could provide information on strength and deformation behavior. The geo-mechanical classification criterion employed in this paper was in accordance with standards widely used today, trying to characterize the analyzed andesites in terms of physical characteristics, strength and deformation.

Keywords: *andesites, aggregate, chemical, geological, strenght, classification*

1. INTRODUCTION

Rocks were used as building materials since antiquity. Over time, their use in various forms, all over the world, has increased, varying by culture and time (Danciu, 2010; Danciu and Buia 2013, 2016). Raw materials like andesites, from Southern Apuseni Mountains, were used for manufacturing different types of tools since the Early Neolithic (Lorinţ and Bărbat, 2014). In Romania, useful rocks are widespread in vorland structures, especially in Carpathian structures. They have multiple uses in constructions, and various other industries. Thus, besides being used as raw stone in constructions,

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roads and other engineering works, they can be used in ornamental-decorative works, depending on the physical-mechanical and aesthetic properties (Danciu and Buia 2016). This wide range of uses makes very important knowing the places which contain fields which are not exploited so farbut whose reserves allow operation in the short run. The construction, rehabilitation and maintenance of road and rail infrastructure sectors implies the use of large amounts of materials, among which the natural aggregates have the largest share. Thus, the rigorous determination of rock qualities where the aggregates, for the above mentioned domains, is absolutely necessary and well-defined periodicity (Danciu and Buia 2013). Using rocks in the execution of various works is allowed only if they meet certain quality criteria. In this context, this study aims to establish the chemistry, mineralogy and geomechanical parameters of andesites from Southerm Apuseni Mountains, in order to exploit them for the construction, rehabilitation and maintenance of road and rail infrastructure sectors. The results will be classified and compared to the limit values set by standards.

2. MINERALOGICAL AND PETROGRAPHIC STUDY

Andesites from Criscior and Albini were previously analyzed both macroscopically and microscopically to determine the mineralogic-petrographic characteristics (Danciu and Buia 2016).

The mineralogic-petrographic study was based on analysis of thin sections using a polarizing microscope. After the macroscopic and microscopic examinations a detailed description of these rocks was possible.

2.1. Criscior Andesite - sample No.1

Sampling location: Criscior, Hunedoara district. Geologic structure: tardive subsequent magmatism (neogenic), second cycle.Rock type: magmatic, effusive (neovolcanic), neutral. Structure: semi-crystalline (hypocrystalline), porphyry-vitreous.Texture: unoriented (massive), compact. Color: dark gray. Mineralogical composition: neutral plagioclase feldspar, hornblende, microlitic vitreous paste, opaque minerals, secondary minerals (kaolinite, sericite, limonite). Plagioclase feldspar (30.5%) is represented by idiomorphic and hipidiomorphic crystals with incipient alteration stages. The plagioclase feldspar appears mostly zoned, with crystals dimensions varying between 0.3/0.2 mm and 2.0/1.0 mm. Central zones of the plagioclase feldspar, with higher anortite content, appear sometimes transformed into kaolinite and sericite. For most of the cases, the microlitic plagioclase feldspar appears not-altered. Hornblende (4.5%) appears with the rock mass as hipidiomorphic crystals, with dimensions below 1 mm. For most of the cases, the crystals contours are opacitized; sometimes, the amphibole is completely transformed into a secondary product through oxy-hydration. The vitreousmicrolitic paste (55%) in this rock type consists of amorphous volcanic glass, where the feldspars microlites appear nonuniformly distributed. As the feldspars, microlites are predominant, the resulting macroscopic color is dark gray. Reaction to acids: none of the rock components reacts with dilute HCl. Denomination rock: vitreous-porphyry Andesite (Toderaş et al., 2017).

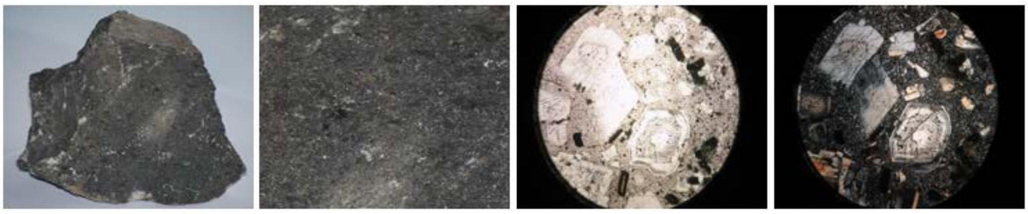

Fig. 1. Criscior Andesite

2.2. Albini Andesite - sample No. 2

Sample location: Albinii-Haneș, Alba District. Geologic structure: neogenic eruptivism of Apuseni Mountains (Metaliferi). Rock type: magmatic, effusive (neovolcanic), intermediary. Structure: hypocrystalline (semicrystalline), porphyry vitreous. Texture: unoriented (massive), compact. Color: grey, slightly dotted. Plagioclase feldspar (23.8%) consists mostly of idiomorphic and hypidiomorphic crystals, rarely zoned. Plagioclase feldspar crystal dimensions vary from 0.01 mm for microlites and 6.2/4.3 mm for phenocryst. For thin sections parallel with crystallographic axis Z and presenting polysynthetic macles (twins), the unidirectional cleavage appears distinctly. Hornblende (12.6%) appears within the rock mass as idiomorphic, hypidiomorphic and xenomorphic crystals with dimensions between 0.2/0.08 mm and 10.3/1 mm.

Fig. 2. Albini Andesite

The sections are either parallel or perpendicular on crystallographic axis Z. Good cleavage appears distinctly, as bidirectional (124°) or basal sections and unidirectional for sections parallel with prismatic faces. Some of the idiomorphic and hypidiomorphic crystals present partial or total opacitization. Microlites (50%) are feldspathic, non-uniformly distributed within the volcanic glass. Opaque minerals (4.5%) are finely crystalized, idiomorphic, hipidiomorphic and xenomorphic, chaotically distributed within the rock paste and consisting of pyrite and oxidic minerals. Secondary minerals, represented by kaolinite, affect partially some plagioclase phenocrysts and microlites. Reaction to acids: none of the rock components reacts with dilute HCl. Denomination rock: Andesite with hornblende (Toderaş et al., 2017).

3. METHODS AND RESULTS

The alkali-aggregate reaction reveals the reactivity and potential harmfulness of aggregates containing one or more forms of low crystalline silica (opal, chalcedony, tridimite, crystobalite) and volcanic glass rich in silica (Danciu, 2010; Danciu and Buia 2013, 2016). By verifying the alkali-aggregate reaction it is established the possibility of using the aggregates together with cements to mitigate or annihilate the reactivity and harmfulness. This determination is required for aggregates used to produce concretes in permanently or alternately contact with water or a wet environment (Toderaş et al., 2017). The results obtained from the analysis are presented in Table 1. The chemical analysis for the two types of andesites were aimed at determining the main oxides. The results of chemical analysis are presented in Table 2.

Table 1. Mean values for alkali-aggregate reaction

Recoltation place/ Rock type	Silica concentration, Sc [mmol/dm^3]	Sodium hydroxide concentrate reduction, Rc [mmol/dm^3]
Criscior/ Andesites	53,5	22,7
Albini/ Andesites	51,3	16,9

Table 2. Chemical composition of andesites from Criscior and Albini

Chemical composition Oxides	Recoltation place/ Rock type		Oxides	Recoltation place/ Rock type	
	Andesites/ Criscior %	Andesites/ Albini %		Andesites/ Criscior %	Andesites/ Albini %
SiO_2	53,5	51,3	ZnO	0,0417	0,0362
Al_2O_3	13,4	13,2	SrO	0,141	0,130
Fe_2O_3	13,1	14,8	Cl	0,0184	-
MnO	0,326	0,342	Ga_2O_3	0,0206	0,0212
MgO	1,91	1,43	Rb_2O	0,0289	0,0232
CaO	12,0	13,00	BaO	0,410	0,408
Na_2O	0,696	0,648	HfO_2	0,0880	-
K_2O	2,46	2,18	CuO	-	0,0302
TiO_2	1,19	1,10	Lu_2O_3	-	0,0756
P_2O_5	0,380	0,323	Ag_2O	-	0,115
SO_3	0,0483	0,547	ZnO_2	-	0,0820
V_2O_5	0,0491	0,0728	HgO	-	0,0411
Cr_2O_3	0,0874	-	Tl_2O_3	-	0,0618
NiO	0,0238	-			

Knowing the physical conditions of the rock can help developing a quantitative description and estimating its influence on strength and deformation characteristics. This can only be achieved by determining the physical characteristics. The determination of physical properties was performed in accordance with current standards (STAS, EN, EN), with the recommendations of the International Bureau of Rock Mechanics (BIMR) and the International Society of Rock Mechanics (Simrit). Methods for the determination and calculation relations are found in various specialty papers (Danciu, 2010; Danciu and Buia 2013, 2016). By determining the physical parameters, according to standards and specific procedures, there were obtained the following average values for the analyzed samples (Table 3 - 4). According to the purpose, there were determined the following resistance and deformation characteristics of the rocks: compressive breaking strength, freeze-thaw resistance, static modulus, Poisson's ratio, continuity index, remanent deformation coefficient and coefficient of heterogeneity, in Tables 5-8. The calculation methods and relations used are consistent with existing STAS and with the recommendations of the International Bureau of Rock Mechanics and International Society of Rock Mechanics, some of them are found in the literature (Danciu, 2010; Danciu and Buia 2013, 2016).

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Table 3. Average values of the physical characteristics of andesites

Rock type / Recoltation place	Physical characteristics					
	Specific density (real) ρ x 10^3 [kg/m^3]	Apparent density (volumetric) ρ_a x 10^3 [kg/m^3]	Total porosity n [%]	Apparent porosity n_a [%]	Pore number e	Compactness c [%]
Criscior/ Andesites	2,6558	2,6397	0,6061	0,3297	0,0060	99,3937
Albini/ Andesites	2,6931	2,6734	0,7339	0,3819	0,0073	99,2660

Table 4. Average values of the physical characteristics of andesites

Rock type / Recoltation place	Physical characteristics			
	Water absorbtion		Saturation coefficient, s	Natural humidity W [%]
	Normal pressure [%]	Boiling [%]		
Criscior/ Andesites	1,4089	1,5315	0,9224	0,7963
Albini/ Andesites	1,1652	1,2375	0,9416	0,6404

Table 5. Average values of the resistance characteristics of andesites

Rock type / Recoltation place	Resistance characteristics				
	Uniaxial compressive breaking strength σ_{rc} [MPa]; [N/mm^2] Specimen status			Softening coefficient after saturation η_s [%]	Coefficient of softening after freeze-thaw η_g [%]
	usc.	sat.	î-d		
Criscior/ Andesites	143,538	129,774	125,297	9,565	12,715
Albini/ Andesites	142,404	1127,852	122,420	10,226	13,997

Table 6. Average values of the resistance characteristics of andesites

Rock type / Recoltation place	Resistance characteristics Freeze-thaw resistance		
	Number of specimens with obvious damage	Gel coefficient μ_g	Elasticity modulus decrease after 25 freeze-thaw cycles Δ [%]
Criscior/ Andesites	0	0,127	8,691
Albini/ Andesites	0	0,113	7,232

Table 7. Average values of the resistance characteristics of andesites

Rock type / Recoltation place	Resistance characteristics Wear resistance			
	LOS ANGELES, LA [%]	DEVAL, R_{uz} [%]	Quality coefficient, C	Resistance to breakage by shock dry, R_c [%]
Criscior/ Andesites	16,369	2,550	2,827	92,016
Albini/ Andesites	11,138	2,600	2,420	92,492

Table 8. Average values of the andesites deformation coefficients

Rock type / Recoltation place	Deformation coefficients				
	Static elasticity modulus, E_s [MPa]	Static Poisson's ratio, μ	Continuity index, I_c [%]	Remanent deformation coefficient, C_r	Heterogeneity coefficient, C_{df}
Criscior/ Andesites	24036,94	0,223	67,352	0,003872	0,81
Albini/ Andesites	24336,23	0,233	82,086	0,002131	0,95

4. DISCUSSION

For the efficiency and success of the classification system used, it must be simple, easy to understand and apply, taking into account only significant and intrinsic parameters of rock that are most relevant in engineering (Deere and Miller, 1966). In this paper we performed a classification of andesites according to the literature (Danciu, 2010; Danciu and Buia 2016; Deere and Miller, 1966; Gercek, 2007; Ramamurthy, 2004; Toderaș, 2008) on the chemical, geological and geomechanical criteria, considering all of them having a significant influence. Depending on the chemical criterion, the rock classification was made based on the chemical composition of rocks and alkali-aggregate reaction, two important criteria in qualitative characterization of the rock.

Table 9. Chemical classification of the rocks

Chemical classification of the rocks	Rock type / Recoltation place	
	Andesite/Criscior	Andesite/Albini
SiO_2 content	Neutral	Neutral
Alkali-aggregate reaction	Non-reactive	Non-reactive

Table 10. The geomechanical classification of the intact rock

The geomechanical classification of the intact rock			Rock type / Recoltation place			
			Andesites/Criscior		Andesites/Albini	
Characteristics	Property	Classification value	Obtained value	Rock characterization	Obtained value	Rock characterization
Physical	Volumetric density	2,251 - 3,000	2,6397	- heavy	2,6734	- heavy
	Apparent porosity	< 1,0	0,3297	- slightly porous	0,3819	- slightly porous
	Water absorbtion at normal pressure	0,50-3,00	1,4089	- slightly absorbant	1,1652	- slightly absorbant
Resistance	Panet compressive breaking strength (1993)	60-200	143,538	- high resistance	142,404	- high resistance
	Compressive breaking strength used in Romania	120-200	143,538	- high resistance	142,404	- high resistance
	Quality coefficient (Deval method)	13-15 > 15	14,177	- very good	16,538	- excellent
	Freeze-thaw behavior	0 < 0,3 < 25	0 0,127 12,715	- resistant	0 0,113 13,997	- resistant
	Bad weather resistance	0 80 - 100	0 90,4	- fresh	0 89,8	- fresh
Deformation	Static elasticity modulus	20000 - 50000	24036,94	- rigid	24336,23	- rigid
	Poisson's ratio	0,2 - 0,3	0,223	- average	0,233	- average
	Deformation behavior	0,001 – 1 0 – 3,125	0,0038 0,810	- elastic behavior	0,0021 0,95	- elastic behavior
	Continuity coefficient	50-75 75 - 90	67,352	-average	82,086	- good
Resistance and deformation	Deere and Miller					
	Monoaxial compressive breaking strength	100-200	143,538	- high resistance	142,404	- high resistance
	E_s/σ_c ratio (Modulus ratio)	< 200	167,460	- low	170,846	- low
	Ramamurthy and Arora					
	Monoaxial compressive breaking strength	110 - 250	143,538	- high resistance	142,404	- high resistance
	E_s/σ_c ratio (Modulus ratio)	100 - 200	167,460	- average	170,896	- average

The geomechanical classification of the andesites was done according to the criteria used today vastly, the rocks being characterized by their physical, resistance and deformation characteristics. Considering the geomechanical criterion, the andesite were classified according to the properties from table 10. Based on the average values of the main physical and mechanical characteristics obtained for the rocks analyzed and compared with the conditions of eligibility, andesites are classified into one of the five admissibility classes (Table 11).

Table 11. Admissibility conditions of the rocks used for rail and road works

Characteristic	Rock class						
	A	B	C	D	E	A	A
	Admissibility conditions					Rock type / Recoltation place	
						Andesite/Criscior	Andesite/Albini
Apparent porosity at normal pressure, %, max.	1	3	5	8	10	0,3297	0,3819
Compressive strength, dry, N/mm^2, min.	160	140	120	100	80	143,538	142,404
Wear Los Angeles car type, %, max.	16	18	22	25	30	16,369	11,138
Crushing compression strength, dry, %, min.	70	67	65	60	50	92,016	92,492
Freeze-thaw resistance:	3						
- Gel coefficient (μ_{25}) ,%, max.						0,127	0,113
- Freeze sensivity (η_{d25}), %, max.						9,565	10,226

5. CONCLUSION

Analyzed andesites are compact, having a high density, resulted from the comparisson between the specific and apparent densities.The compressive breaking strength of the analyzed andesites is high, between 140-145 MPa, admissibility class B. The wear resistance has low values, while the dry crushing compressive strength has values above the ones imposed for the admissibility class A, these rocks being recommanded for rails and road works. Depending on the values obtained for the gel coefficient and the softening coefficient after freeze-thaw cycles, we consider these rocks to be freeze-thaw resistant. By comparing the obtained results with the admissibility conditions, the analyzed rocks are classified in the admissibility class A. Due to the resistance to bad weather and wear, and because of the high polishing capacity, the analyzed andesites may be used in constructions, as decoration rocks inside and outside, for monuments. For larger projects, the andesite may be used as structure element. The andesite road borders are more lasting and fashionable than the ones from concrete. Also, because of acid rain intensification (due to growing pollution), the andesite replaces marble for monuments, because it lasts more and doesn't reacts with acids. The andesites from Criscior and Albini used nowadazs as aggregates for roads may extend their capitalization domains: for rail works, constructions, ornaments, monuments and for manufacturing andesite prefabricates.

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STUDY OF THE BEHAVIOR OF BUILDINGS SITUATED IN THE AREA OF INFLUENCE OF UNDERGROUND MINING OF THE THICK COAL SEAMS FROM THE JIU VALLEY MINING BASIN, BY 3D FINITE ELEMENT MODELLING

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Abstract: *This paper refers to the analysis of surface deformations generated by the underground mining of coal deposits and their influence on a two-level and three-level reinforced concrete building using 3D finite element modeling. Are considered the longwall mining method, with the collapse of the surrounding rocks and the top coal caving mining methods, in several extraction sequences.*

Keywords: numerical modelling, finite element, *subsidence, horizontal displacement, coal seam, underground mining, building, reinforced concrete, strain.*

1. DESCRIOPTION OF THE FINITE ELEMENT MODELS

The purpose of the researches undertaken in this chapter was to study the behavior of the surface [3], [4], [8], [9], [16] and constructions located on the surface of the coalfields from the Jiu Valley, by extracting a thick seam, with low inclination, in the case of different systems of mining the inclined slices. To achieve this goal the 3D finite element modeling was used, with CESAR-LCPC software, version 4 and the processor CLEO 3D [1], [2], [13], [15].

The modeling of the field subjected for mining, considered continuously, homogenous and isotropic, was performed for the conditions of a thick seam of horizontal coal, with an average thickness of 9m, respectively 8m, at an average depth of H = 300m, measured from surface – the most common depth of the thick coal seam no. 3, in the low inclined areas from the Jiu Valley (e.g. Paroseni, Lupeni or Livezeni mining fields) – figure 1.

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For the result to be significant, seam no. 3 with a thickness of 9m (Figure 2. a) and respectively 8m (Figure 2. c) was imagined to be mined in the final phase in a panel with a total extinction of X_{ca} = 400m and a longwall with a length of l_{ab} = 150m [17].

Under the above mentioned conditions, the extraction of seam no. 3 was simulated, with a thickness of 9m, in three inclined slices, with high/thickness h_{ex} = 3m, mined in successive order, from top to bottom (Figure 2. a) and extracted all over the entire thickness between the bed and the roof (Figure 2 c). Also, the thickness of 8m was considered to be divided into two slices with a height of h_{ex} = 4m, mined in descending order (Figure 2. b) [12].

Although in the modeling hypothesis it was simplistically considered that the surrounding rocks and the coal are continuous, homogeneous and isotropic environments, methods and technologies with longwall, in retreat / with pillars, were considered as guiding the mining pressure by total collapse of the rocks from the roof (the cases represented in the schemes of figures 2. *a* and *c*) [12] and with top coal caving (case from figure 2. *b*) [14].

Regarding the building with 1, 2 and 3 levels, with its projection sizes in the horizontal plane of 20m, following the *x* axis and 10m, following the *y* axis, they were arranged on the vertical line of the mined panel centre. The levels, with height of 2,7m, were separated from each other by reinforced concrete ceilings, so as to result: a building with one level, with a height of 2.7m; with two levels, with a height of 5.4m; with three levels, to the total height of 8,1m.

Each level has been designed, on the long sides, with 4 windows, with dimensions of 1.2 m x 2 m, and on the short sides, with a single window, with size of 1m x 1.2 m (Figure 1).

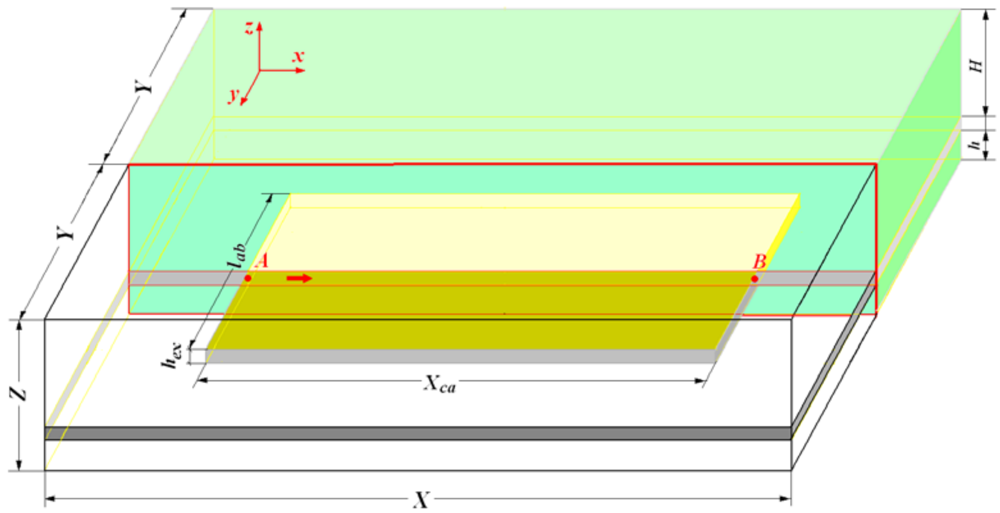

Fig. 1. The schematic diagram of the 3D symmetric model with finite elements for the analysis of the influence of underground mining of a thick seam with low inclination on the surface [1], [2]

As can be seen in figure 2, in several computational models, were captured 12 phases / sequences of extraction of the longwall face, starting from the attack gallery from point *A* to the stopping / disassembling point of the face *B*, and for each extraction system schematized in figure 2, respectively, for X_{ca} = 50m, 100m, 140m, 170m, 190m, 200m, 210m, 230m, 260m, 300m, 350m, 400m. So, for each building (with one level, two and three levels), 72 models were created, resulting in a total of 216 models, which required over 350 calculation hours [1], [2].

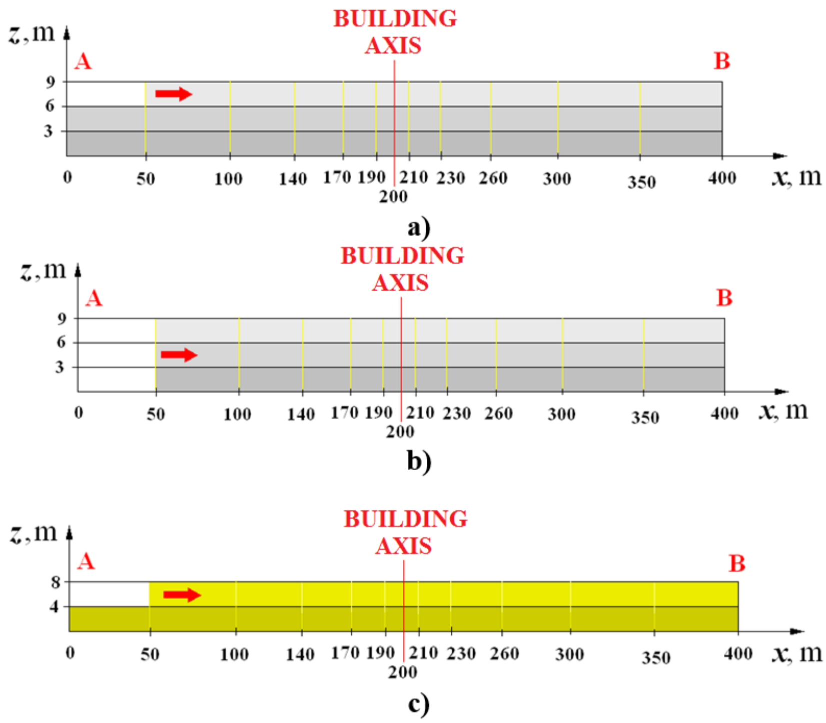

Fig. 2. Variants of the modeling of the extraction by longwall mining of a thick coal seam, with low inclination, from the Jiu Valley mining basin [1], [2]

a) extraction of the first 3m slice, with the collapse of the rocks from the roof; *b*) full extraction of the 9m seam, with top coal caving; c) extraction of the first 4m slice, with the collapse of the rocks from the roof;

Because of the model symmetry after the *z*0*x* vertical plane, following the direction of coal face advancement, in view to reduce the model sizes and implicitly to decrease the computation time, a symmetrical model was adopted by using that cutting plane (Figure 1). Finally, a basis model has resulted, with the sizes of *X* = 2 500 m, *Y* = 500 m and *Z* = 409 m.

Regarding the rock massive representation, it was obtained from a plan meshing finite triangular elements model and by their sequential “extrusion” following the “*z*” axis, resulting volume finite elements with triangular prism shape, with the height disposed after that axis.

Because of the large volume of the rock massif models, of $511.25 \cdot 10^6$ m^3, requiring significant computing resources, to represent the building in the finite element model, respectively to generate the building walls and ceilings, we used also the “extrusion” tool of the CLEO3D processor, but this time applied to a linear finite element, to design the “shell” type surface finite elements, with thickness of 0.3m [1], [2], [11], [13], [15].

The calculations made on the finite element models of „shell” type, have led to the following results, regarding the stresses developed in the construction structure: the state of stress in the reference system „0,*x*,*y*,*z*”, $\sigma_x, \sigma_y, \sigma_z, \sigma_{xy}, \sigma_{yz}, \sigma_{zx}$, in KN/m^2; the maximum, average and minimum stresses $\sigma_1, \sigma_2, \sigma_3$, in KN/m^2; specific forces, $N_x, N_y, N_z, N_{xy}, N_{yz}, N_{zx}$, in KN/m; the specific bending moments, $M_x, M_y, M_z, M_{xy}, M_{yz}, M_{zx}$, in kN; the stresses after Von Misses criterion, *v*33, in KN/m^2.

Generating the base finite element model (from which the 216 particular models derived) was based on the following constructive elements: 23 712 nodes, 540 surface elements and 40 843 volume elements.

To implement the boundary conditions of the model, the following restrictions were imposed: for the lower limit the movement along the *z*-axis was blocked, and for the lateral limits, the movements along the axes *x* and *y* - maintaining the freedom of movement for the other directions and for the surface.

Regarding constitutive materials laws used in the models, considering the very large sizes of the models, to reduce the computation time, an elastic behaviour hypothesis was chosen for both, the massive rocks and reinforced concrete of the building. This choice was determined by the fact that, in the case of similar models made by Marian [7] and Ştefan [20], using for the rock massive both laws of behaviour, elastic and elastic-plastic, the difference between results was non-significant. Therefore, in these models, for the massive rocks, the following characteristics have been adopted [6], [23]: average apparent density $\rho_r = 2\,663\,\text{kg}$ /m^3, elasticity modulus $E_r = 1.511 \cdot 10^6\,\text{kN}$ /m^2 and Poisson's ratio $\nu_r = 0.19$; and for concrete, the following properties [19], [21], [22]: apparent specific density $\rho_b = 2\,500\,\text{kg}$/m^3, elasticity modulus $E_b = 30 \cdot 10^6\,\text{kN}$/m^2, Poisson’s ratio $\nu_b = 0.2$, cohesion C_b = 2 200 kN /m^2, angle of internal friction $\varphi_b = 55^o$, compressive strength $R_{c,b}$ = 16 000 kN /m^2 and tensile strength $R_{t,b}$ = 1 200 kN /m^2.

In the computations, the model charging “phases” option was used, with MCNL module of the CESAR solver. The initial phase of model charging was geostatic, with the average vertical stress of $\sigma_z = \gamma_r \cdot H$ = 8MN /m^2 and horizontal stress of $\sigma_x = \sigma_y = k_{ox} \cdot \sigma_z = k_{oy} \cdot \sigma_z$ = 2.64MN /m^2; the building was loaded by gravity, with the specific weight of the concrete.

2. THE EVALUATION OF THE IMPACT OF UNDERGROUND MINING SYSTEM ON BUILDINGS WITH ONE, TWO AND THREE LEVELS AFTER VON MISSES CRITERION

This criterion is widely used in the numerical modelling and it is based on that fact that, a material deforms when the potential deformation energy of the body shape reaches a critical value [10], [18]:

$$\sigma_{ech} \leq \sigma_{at} \tag{1}$$

where: σ_{ech} represents the equivalent stress of the material;
σ_{at} - allowable tensile strength of the material.

Expression of the equivalent stress is given by the relation:

$$\sigma_{ech} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1 \cdot \sigma_2 - \sigma_1 \cdot \sigma_3 - \sigma_2 \cdot \sigma_3} \tag{2}$$

where: σ_1, σ_2 and σ_3 $(\sigma_1 > \sigma_2 > \sigma_3)$ are the main stresses for the three directions (the maximum, medium and minimum).

2.1. The impact of underground mining on a building with one level

From the analysis of the data obtained from the numerical modeling (Figure 3) it is found that in the situation of underground mining of the first slice, indifferently of the thickness of the slice, the maximum stresses exerted on the building develops in a wide range of values, having a strong upward character manifested with the advance of the longwall face.

Thus, in the case of extracting the first slice of 3 m thickness, starting with the second sequence of extraction (X_{ca} = 100 m), the maximum stress on the building is in the range of 6.740 kN/m^2 $\div$ 76.600 kN/m^2. From this moment, the affected main part of the building is the foundation and the side from the extracted space (Figure 3). After the full extraction of the first slice of 3m, it is affected the entire structure of the building.

After the entire extraction of the first slice, the stresses developed in the structure of the building continue to grow at a lower rate, from a value of 76.600 kN/m^2 to 78.400 kN/m^2, in the situation of extracting the second slices; and then will reach 79.600 kN/m^2 at the time of total extraction of the third slice.

In the case of top coal caving mining method, the behavior of the building is almost identical to the case of 3m slices extraction, with collapse of the rocks from the roof, specifying that the variation of the maximum stresses has a strong upward trend and is in the range of 7.400 kN/m^2 79.600 kN/m^2. Accordingly, the building is affected much more intensely, compared to successive slices, with the directing of the pressure through the complete collapse of the rocks from the roof.

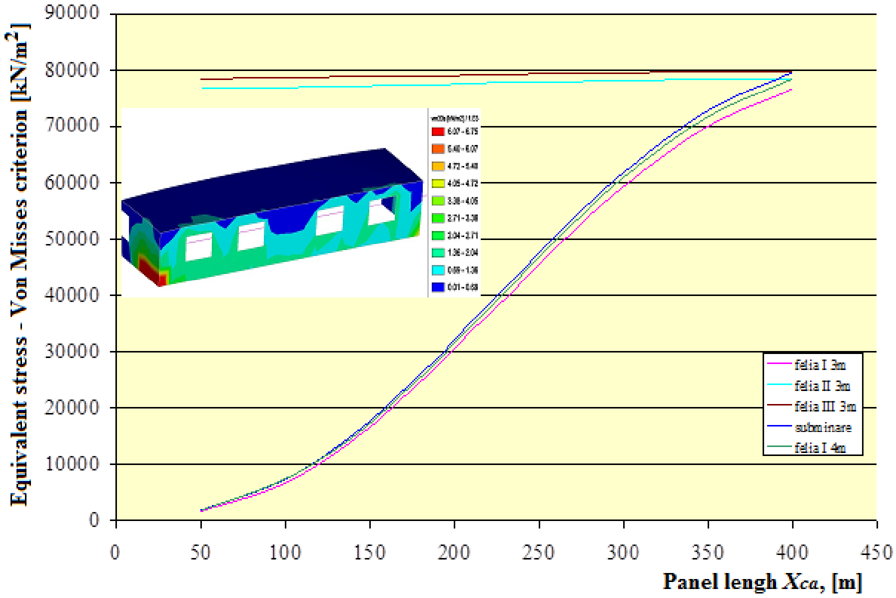

Fig. 3. Evolution of the equivalent stresses, according to the Von Misses criterion, depending on the method of extraction and seam thickness, for a single level building [1], [2]

2.2. The impact of underground mining on a building with two levels

In the case of a two levels building, as in a single level building case, it is ascertained that the extraction of the first slice, regardless of its thickness, the maximum stresses exerted on the building develop over a wide range of values, having a strong upward increase with the forwarding of the longwall face (Figure 4).

At the extraction of the first slice of 3m thickness, starting with the second extraction sequence (X_{ca} = 100m), the maximum stresses to which the building is subjected are in the range of 6.780 kN/m^2 78.200 kN/m^2. From this stage, are affected the foundation and the closest side to the extracted space, from the first level of the building (Figure 4). After the entire extraction of the first slice, the whole structure of the building is affected, mainly in its lower part, located between the foundation and the walls.

By continuing to extract the thick coal seam in the second slice, the maximum stresses in the structure of the building continue to increase, but in this case at a lower rate, from the value of 78.200 kN/m^2 to the value of 80.100 kN/m^2, after the complete extraction of the second slice, respectively up to 80.200 kN/m^2, at the time of completion of the third slice extraction.

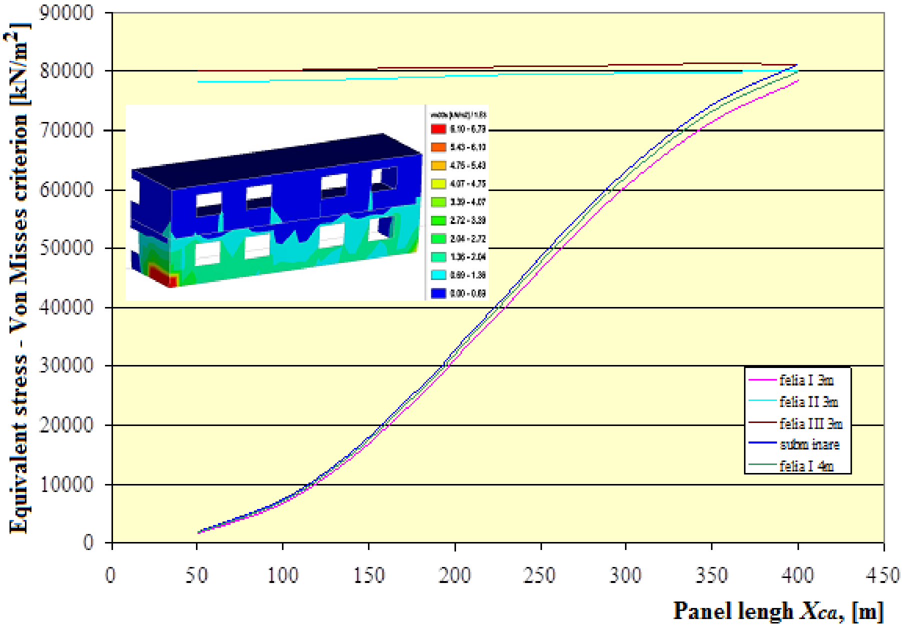

Fig. 4. Evolution of the equivalent stresses, according to the Von Misses criterion, depending on the method of extraction and seam thickness, for a building with two levels [1], [2]

In the case of extraction of the coal seam using the top coal caving method, on all 9m thickness, the behavior of the building is similar to that presented at the extraction in slices, with the total collapse of the rocks from the roof, specifying that the variation of the maximum developed stresses in the building have an increasing trend in the range of 7.440 kN/m^2 ÷ 81.300 kN/m^2.

The use of the top coal caving mining method contributes to producing much higher stresses which, consequently, will deeper affect the building, compared to those developed in the structure of the building as a result of applying the previous mining method [5].

2.3. The impact of underground mining on a building with three levels

Next, we analyze the behavior of a three-story building under the influence of the underground mining of a thick coal seam. Just as in the other two cases (one-level or two-level buildings), the extraction of the first slice, irrespective of its thickness, has a major influence on the maximum stresses exerted on the building, which, as in the other two cases develop in a wide range of values, which increase strongly with the forwarding of the longwall face (Figure 5).

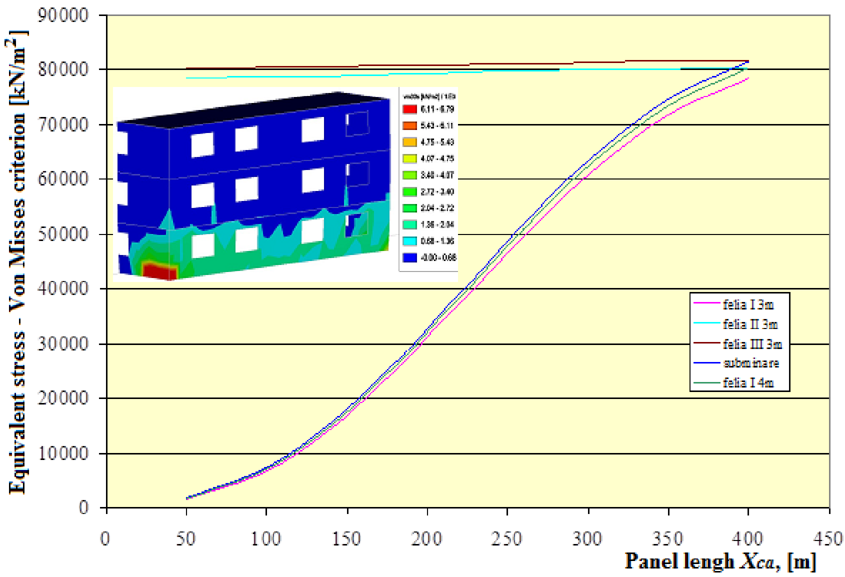

Fig. 5. Evolution of the equivalent stresses, according to the Von Misses criterion, depending on the method of extraction and seam thickness, for a building with three levels [1], [2]

Starting with second sequence of the coal seam mining (for X_{ca} = 100 m), the maximum stress, to which the building is subject, develops in the range of 7.450 kN/m^2 ÷81.600 kN/m^2. In this case, the building is affected especially in the foundation and in the structural parts situated from the coal face, on the first level (see figure 5). After the panel full mining, the main structural parts of the building affected are limited to levels I and II, in the area between foundation and walls, under the windows respectively (Figure 6).

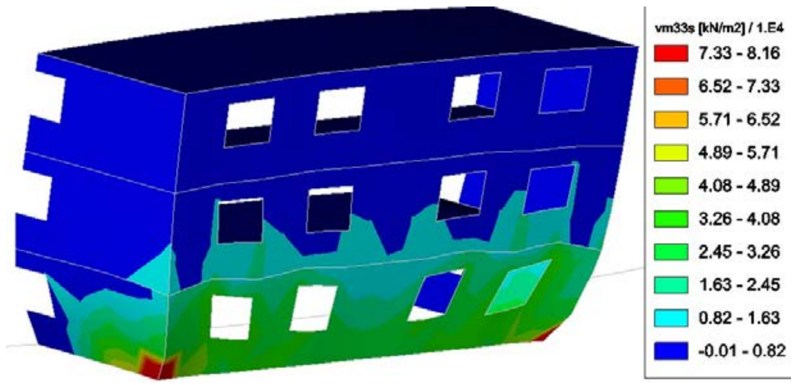

Fig. 6. Damage mode of a building with three levels, according to Von Mises criterion, if the case of using of the top coal caving longwall mining method and for a panel length of X_{ca}= 400 m

The further extraction of the second and third slices causes the equivalent maximum stresses affecting the structure to continue its increasing trend but at a slower rate, starting at a value of 78.400 kN/m^2, up to the value of 80.300 kN/m^2 in the case of the extraction of the second slice, up to the level of 81.700 kN/m^2 at the time of the complete extraction of the three slices.

The extraction of the thick coal seam, by using the top coal caving longwall mining method, induces to the building a similar behaviour to that caused by the mining in slices, with caving rocks roof control, mentioning that the variation of the maximum stress generated in the building structure has a more pronounced increasing tendency.

3. ANALYSIS OF THE MINIMUM AND MAXIMUM PRINCIPAL STRESSES GENERATED BY THE UNDERGROUND MINING ON BUILDINGS WITH ONE, TWO AND THREE LEVELS

The study of minimum and maximum main stresses development, generated by underground mining on the modeled building structure, revealed that they are influenced directly only by mining system, rather than the loads developed by the building weight. Consequently, further, will be presented the mode of manifestation of the minimum and maximum main stresses for a single-level building, and for the other cases (two-level building, three-level building), will be analyzed only the effects that the main stresses have it on the buildings under study.

Assessment of the behaviour of structural building elements under the main stresses action is based on by maximum normal stress theory. Based on this theory, the stability limit condition occurs when the resistance element reaches the maximum main stress at the tensile / compressive simple loading [10], [18].

If the $|\sigma_1| > |\sigma_3|$, the equivalent stress, after the maximum normal stress theory is:

$$\sigma_{ech} = \sigma_1 \le \sigma_{at} \tag{3}$$

and if $|\sigma_1| < |\sigma_3|$ then:

$$|\sigma_{ech}| = |\sigma_3| \le \sigma_{ac} \tag{4}$$

where: σ_{at}, σ_{ac} is the allowable tensile stress, respectively compressive stress.

3.1. Stability analysis on the single-level building

3.1.1. Study of the maximum main stresses σ_1

Regarding the maximum main stresses σ_1, as in the case of the minimum main stresses, the tension dynamics is related to the extraction system.

Under the conditions of underground mining of the thick coal seam in slices, are distinguished the same two stages also identified at the minimum main stresses, while in the case of applying the top coal mining method, a single stage is identified [5].

Their development areas are: between 1.640 kN/m^2 ÷ 31.800 kN/m^2 for the extraction of the first slice with a thickness of 3m; between 31.800 kN/m^2 ÷ 32.600 kN/m^2 at the extraction of the second slice; between 32.600 kN/m^2 ÷ 33 100 kN/m^2 for the third slice and 1.840 kN/m^2 ÷ 33.100 kN/m^2 in the case of top coal caving mining method.

Regarding the way how the building is affected by the maximum tensions, tensile stresses, developed according to the extraction system (Figure 7), there is a noticeable impact on the ceiling, the corners of the windows and the building wall, which is closest to the longwall face, when it is in the second sequence of the numerical model (for X_{ca} = 100m).

The expansion of the areas affected by the underground mining continues so that at the end of extraction, the building is affected in its entirety (the areas where the main concentration of the main tensile stresses is the corner of the windows, the joining between the side walls, the front walls and the ceiling of the building, the wall portion between the windows and the window lintels).

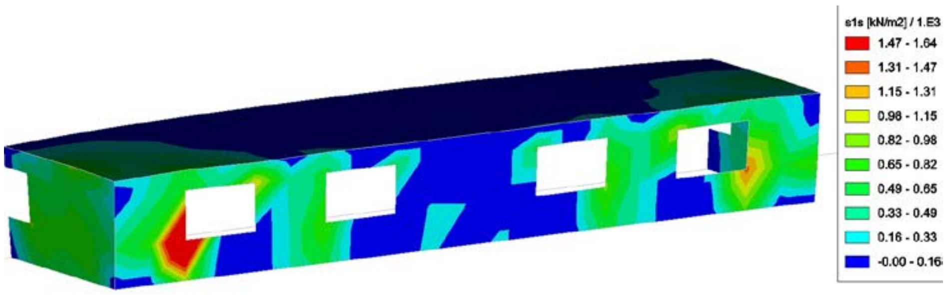

Fig. 7. The distribution of the maximum stresses, tensile stresses, in the structure of a single-level building with the extraction of the first slice, with a thickness of 3 m and an expansion of the extracted space X_{ca} = 100 m [1], [2]

3.1.2. Study of the minimum main stresses σ_3

From the analysis of the minimum stresses, compressive stresses, developed in the structural elements of a single-level building (Figure 8), it can be seen that they occur from a value of -7.000 kN/m^2 in the case of the first slice, of 3m thickness, in the second sequence of the model (when the extension of the extracted space after the X axis is X_{ca} = 100 m), up to a value of – 80.800 kN/m^2, when the slice I is fully extracted (for X_{ca} = 400 m).

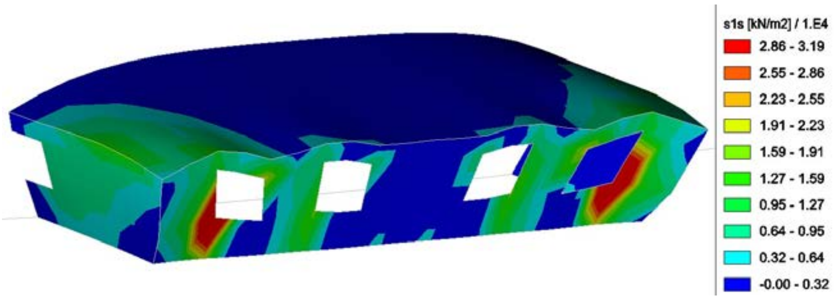

Fig. 8. The way in which a single-level building is affected by the maximum main stresses, tensile stresses, in the case of extracting the 3rd slice, with a thickness of 3 m and an extension of the extracted space X_{ca} = 400 m [1], [2]

After the whole extraction of the first slice and continuing the extraction of the coal seam with the second and third slices, the increase of the compression stresses σ_3 occur in a slower rate, compared to their growth rate in the case of the first slice; so that the value of the minimum main stresses, compressive stresses, increases from -80.800 kN/m^2 to -84.000 kN/m^2 towards the end of the third slice extraction.

As in the case of the stresses calculated according to the Con Misses criterion, it is observed that, in the case of underground mining of the coal seam in slices, with the collapse of the rocks from the roof, there is an increased growth of the minimum main stresses σ_3 during the extraction of the first slice, regardless of its thickness.

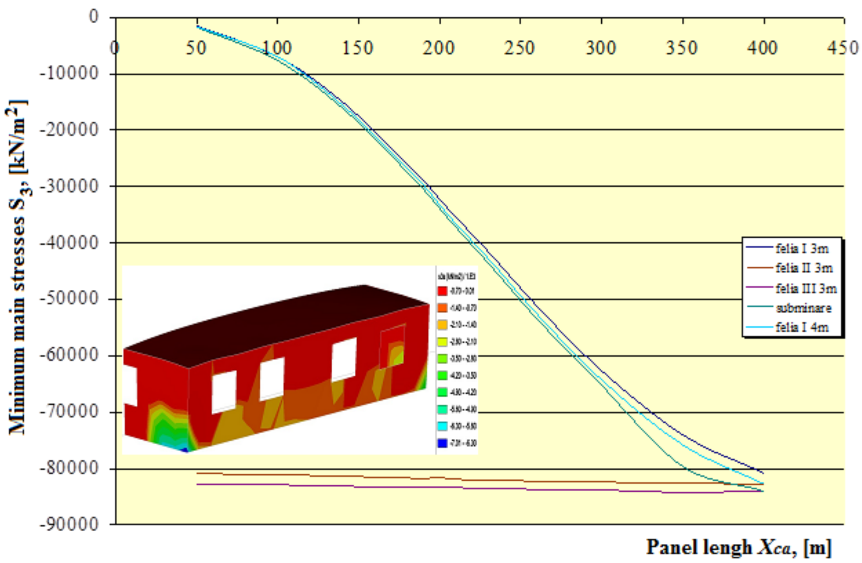

Fig. 9. Evolution of the minimum main stresses σ_3, compression stresses, in the structure of a building with one level, depending on the method of extraction and seam thickness [1], [2]

When the longwall face is in the second sequence of the model (X_{ca} = 100 m), the main affected elements of the building are the foundation, the window sill and the closest part of the building to the longwall face (see figure 9). Then, the degradation of the building continues, so that at the end of extraction of the coal seam, the building is completely affected, the most affected areas being the corners of the windows, the joining between the side walls, the front walls and the foundation (Figure 10).

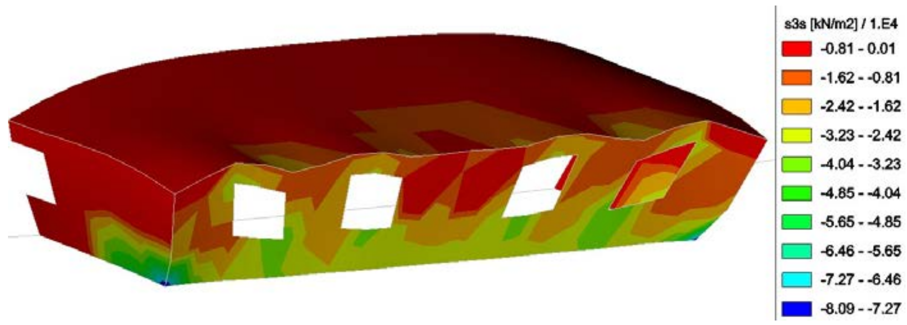

Fig. 10. The behavior of a single-level building due to tensions σ_3, following the extraction of the third slice, with a thickness of 3 m, for X_{ca} = 400 m [1], [2]

If at the underground mining of the coal seam in slices, with the complete collapse of the rocks from the roof, it can be concluded that the evolution of the main minimum stresses in the structural elements of the construction occurs in two phases namely: the accelerated development phase, which coincides with the extraction of the first slice, followed by a phase of slow development of the stresses; in the case of top coal caving longwall mining, the second phase does not take place, the maximum stress σ_3 being reached at the end of the first phase of development of the minimum stresses, when the effects on the building are much more pronounced.

3.2. Stability analysis on the two-level building

3.2.1. Study of the maximum main stresses σ_1

With regard to the maximum main stresses, tensile stresses, to which a two-level building is exposed, these fall within the range of: 1.610 kN/m^2 $\div$ 31.500 kN/m^2, for the extraction of the first slice, with a thickness of 3 m; 31.500 kN/m^2 $\div$ 32.200 kN/m^2, during the extraction of the second slice, with a thickness of 3 m; 32.200 kN/m^2 $\div$ 32.700 kN/m^2, in the case of extraction of the third slice and 1.810 kN/m2 32.700 kN/m^2, in the situation of extraction of the coal seam by top coal caving longwall mining.

Depending on the moment captured in the advancement of the longwall face, the main areas of the construction affected by the underground mining are: the side wall of the building closest to the longwall face, the facade of the building and the upper and lower corners of the first floor windows, the joining area of the building facade with the sidewalls, both at the first level and at the upper level (for the first slice, with a thickness of 3 m and an extension of the extracted space X_{ca} = 100 m); the facade and the lower and upper corners of the windows at the two levels of the building, the joining area of the building facade with the sidewalls, both at the first level and at the upper level (for the end extraction of the third slice, respectively for X_{ca} = 400 m) - Figure 11.

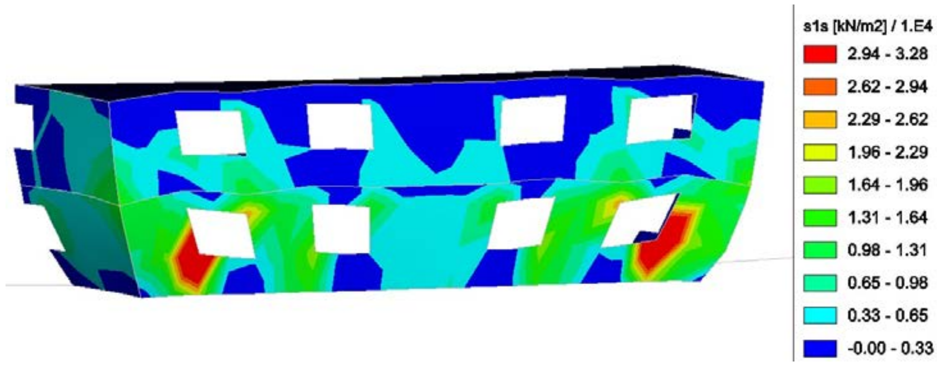

Fig. 11. The behavior of a two-level building by the maximum main stresses, tensile stresses, in the case of extraction of the third slice, with a thickness of 3m, for X_{ca} = 400m [1], [2]

3.2.2. Study of the minimum main stresses σ_3

In the case of a two-level building, the range of minimum main stresses, compressive stresses, is between -6.950 kN/m^2 ÷ -81.200 kN/m^2, in the case of extraction of the first slice of 3 m thickness, with the guidance of the mining pressure by complete collapse of the rocks from the roof; between -81.200 kN/m^2 ÷ -83.100 kN/m^2 for the extraction of the second slice and between -83.200 kN/m^2 and 84.400 kN/m^2 for the extraction of the third slice.

The underground mining of the coal seam bi top coal cavind longwall mining results in a development of the minimum main stresses in the range of -7.640 kN/m^2 ÷ -84.400 kN/m^2.

The main structural elements of the affected building, in the case of the underground mining of the coal seam in slices, with the complete collapse of the rocks from the roof (when the extinction of the extracted space X_{ca} = 100 m) are placed at the first level of the building and comprise: the foundation, the window sill, the lower side of the lateral wall closest to the longwall face and the sidewall engagement zone with the foundation and facade of the building.

The influence of the minimum main stresses on the building occurs with the advancement of the longwall face so that after the extraction of the third slice, of 3m thick, the main affected areas of the building are (Figure 12): the foundation in its entirety, the windows sill, the upper corners of the windows, first level floor and window sill on the second level.

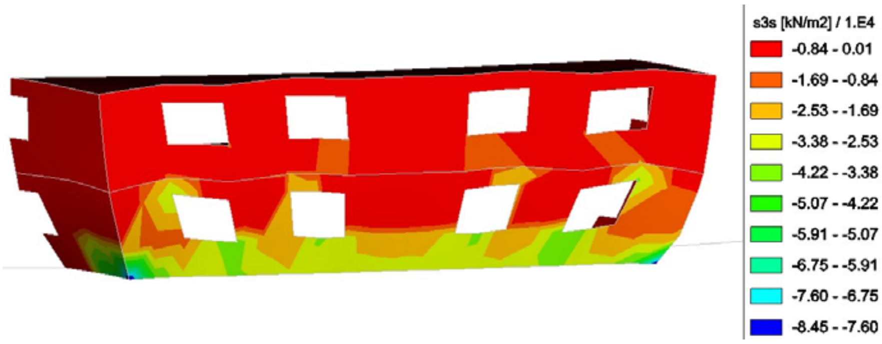

Fig. 12. The behavior of a two-level building by the minimum main stresses, compressive stresses, in the case of extraction of the third slice, with a thickness of 3m, for X_{ca} = 400m [1], [2]

3.3. Stability analysis on the three-level building

3.3.1. Study of the maximum main stresses σ_1

Depending on the system of extraction of the thick coal seam, the maximum main stresses, tensile stresses, can vary with the advancement of the longwall face, as follows: for underground mining in slices, in a 3 m slicing thickness, the field of growt of the maximum main stresses, depending on the number of the extracted slice, is between 1.650 kN/m^2 and 31.700 kN/m^2 for the first slice; between 31.700 kN/m^2 and 32.400 kN/m^2, in the case of extraction of the second slice; between 32.400 kN/m^2 and 32.900 kN/m^2 at the extraction of the third slice.

The influence of the maximum main stress σ_1, of traction, on a building with three levels was studied by analysing the affected areas in the two moments of mining, namely: when longwall face is situate in a second sequence of the model (for X_{ca} =100m) and the case in which the panel mining has been completed. In the first case, the main affected areas are the face of the building and the upper and lower corners of windows, in the top two levels of the building, the joining zone of the façade with the sidewalls (both the first level, and the upper level) and the side wall of the building at the first level, closest to the coal face line.

In the second situation, shown in figure 13, the main affected areas are: the building facade and the upper and lower corners of windows in the top two levels of the building, the joining zone of the building face and the sidewalls, at the first level and at the upper side walls, so at the first level, and the other two levels.

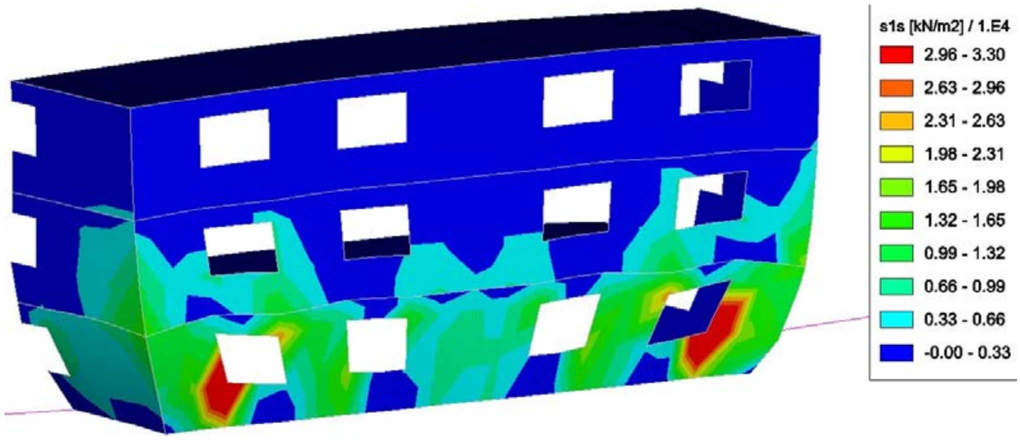

Fig. 13. Damage of a three-level building by the maximum main stresses, tensile stresses, in the case of extraction of the third slice, with a thickness of 3m, for X_{ca} = 400m [1], [2]

3.3.2. Study of the minimum main stresses σ_3

Developing domain of the main minimum compressive stresses σ_3, in the structural elements of the building with three levels, is between: -6.950 kN/m^2 and -81.400 kN/m^2, for the extraction of the first slice, with a thickness of 3m; -81.400 kN/m^2 ÷ -83.400 kN/m^2, for the extraction of the second slice, with a thickness of 3m; -83.400 kN/m^2 ÷ -84.600 kN/m^2, for the 3rd slice, with a thickness of 3 m. And as a result of using the top coal caving mining method, the minimum main stress has the values ranging in the interval of 7 360 kN/m^2 ÷ 84 600 kN/m^2.

In the case of application of the underground mining method in slices, when the extension of the extracted space X_{ca} has a value of 100 m, the main structural elements of the building, affected by the underground mining, are situated at the first level of the building and include: foundation, the window parapet, the lower part of the side wall closest to the longwall face and the joining line between the side wall and the foundation and the building facade.

The minimum main stresses σ_3**,** compressive stresses, are developing in the same time with the coal seam mining advancement, so that the main areas of the building affected are the followings (Figure 14): foundation as a whole, the window parapet, the upper and lower corners of the windows, the ceiling of the first floor level and the partial window parapet of the second level, the joining area of the side walls with the foundation and the building facade.

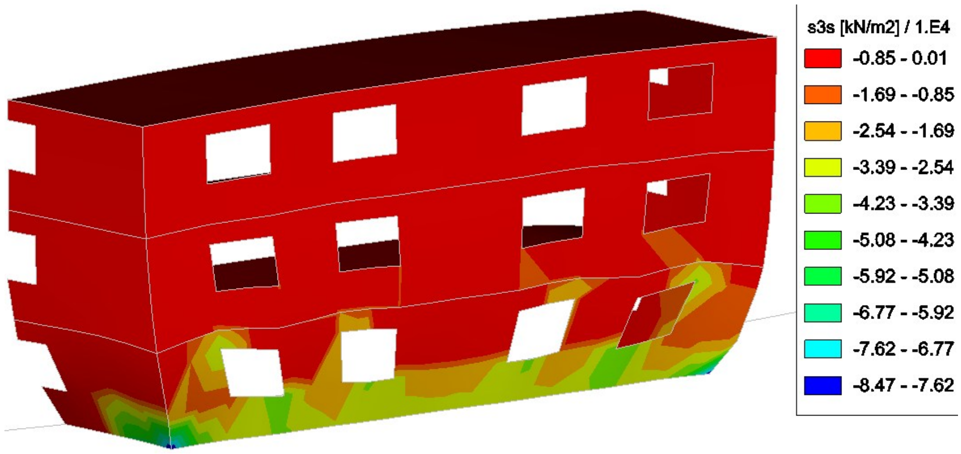

Fig. 14. Damage of a three-level building by the minimum main stresses, compressive stresses, in the case of extraction of the third slice, with a thickness of 3m, for X_{ca} = 400m [1], [2]

4. CONCLUSIONS

The aim of the researches carried out is to analyse the behaviour of the reinforced concrete buildings with one, two and three levels, situated in the influence area of underground mining of a coal seam, with certain extraction systems and different coal seam extraction sequences.

To reach the research objectives a finite elements in 3D modelling was made, using the software CESAR-LCPC, version 4 - processor CLEO3D, of a deposit containing a horizontal thick coal seam with an average thickness of 9m, respectively 8m, located at an average depth of H = 300m. Buildings of reinforced concrete, with a level, two and three levels, situated at the surface, had been modelled by the shell finite elements, with a thickness of 0.3 m.

The simulation of the coal seam mining with a longwall face of 150 m of length, in a panel with overall extension of 400 m, was analysed for 12 extraction sequence of the mining panel, by applying the following extraction systems: a) the 9m thick coal seam is extracted in three successive slices with a thickness of 3m and guidance of the mining pressure trough complete collapse of the rocks from the roof; b) the 8m thick coal seam is extracted in two successive slices of 4m each, with guidance of the mining pressure trough complete collapse of the rocks from the roof; c) the 9m thick coal seam is fully extracted by top coal caving longwall mining.

Based on the above-mentioned combinations, 72 models were built for each building (with 1, 2 and 3 levels), resulting in a total of 216 models that required over 350 calculation hours.

Due to the very large dimensions of the models (X = 2500 m, Y = 500 m and Z = 409 m), in a simplified way, the environments of the models were considered to be continuous, elastic and isotropic and the loading of the models was done geostatically, for massive and gravitational for building.

The results of the calculations made on the 216 models consist of the vertical and horizontal stresses and displacements, for the rock mass and the state of stress, specific forces and moments for the structural elements of the buildings.

According to the Von Misses criterion, of the impact of the underground mining system on buildings with one, two and three levels, the maximum stresses exerted on the building have a strong ascending character with the advancement of the longwall face in the situation of extracting the first slice, irrespective of the thickness of the slice, and develops in a wide range of values (6.740 kN/m^2 $\div$ 76.600 kN/m^2 in the case of a building with a level, of 6.780 kN/m^2 $\div$ 78.200 kN/m^2 for a two-level building and 6.790 kN/m^2 78.400 kN/m^2, in the case of a three-level building).

In the case of the extraction of the second and third slices, the increase of the maximum stresses occurs at a slower rate, compared to the first slice: from 76.600 kN/m^2 to 79.600 kN/m^2, at the moment of total extraction of the third slice, in the case of a building with a level; from 78.200 kN/m^2 to 80.200 kN/m^2, at the end of extraction of the third slice, for a two-levels building; from 78.400 kN/m^2 to 81.700 kN/m^2 at the end of extraction of the third slice, in the case of a three-level building.

In the case of underground mining of the coal seam by top coal caving longwall mining, the behavior of the building is identical to the one from the situation of the extraction of the coal seams in slices. But the way the building is damaged is a more serious one, compared to the one from the extraction in slices.

From the study of the maximum and minimum main stresses exerted on a building with one, two and three levels, it was found that both the maximum and the minimum stresses developed in two stages, in the situation of extraction of the seam in slices and one-stage in the case of extraction by top coal caving longwall mining.

The areas most affected by the maximum and minimum main stresses on the building, regardless of the number of levels, are: the lower and upper corners of the windows, the joining areas of the walls, the joining areas of the walls with the foundation.

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ANALYSIS OF SURFACE BEHAVIOR AS A RESULT OF UNDERGROUND MINING OF TWO COAL SEAMS BY INFLUENCE FUNCTION METHOD

DACIAN-PAUL MARIAN [1]

Abstract: *The underground mining of a deposit leads inevitably to the deformation of the surface as well as to the destruction of the objectives located in the area of influence of the extraction. The problem of surface deformation as a result of underground mining has occupied and still occupies an important place in the mining field scientific research. Solving this problem makes it possible to predict the effects of the underground mining on the surface and offers the possibility of taking appropriate measures to protect the objectives located in the area of influence of the extraction. This paper analyzes the problem of surface deformation as a result of the simultaneous extraction of two horizontal coal seams, through applying the influence function method.*

Keywords: *underground mining, subsidence, horizontal displacement, prognosis, influence function method.*

1. GENERALITIES

The need to study the phenomenon of surface deformation as a result of underground mining of useful mineral substances has occurred with the development of mining and, in particular, with the transition from a predominantly surface extraction (open-pit) to underground mining [2], [3], [6], [7], [19].

The subsidence phenomenon is still being studied and will be studied in the future as it is a topical issue grounded upon the need to protect surfaces and constructions from surface or underground mining works, communication paths, utility networks, etc. [2], [4], [5], [12], [14].

In the case of the underground mining of two or more nearby seams, the problem of reducing the mining effects is very difficult [8]. Thus, the objectives located in the area of influence of the extraction can be protected by a harmonic extraction of the seams, with the aim of reducing the tension and compressive stresses appearing on the surface [16]. Otherwise, through a misalignment of the panel, these

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stresses may increase, leading to the destruction of the objectives located in the area of influence of the extraction [9], [20].

In order to reduce the tensions appeared on the surface, it is necessary to extract the two seams concomitantly, with the offsetting of the panels. The gap between the panels, from the nearby seams, must take into account that deformations whose size exceeds the permissible limits must be compensated by the deformations of the sign contrary which are born in the rock massif.

2. INFLUENCE FUNCTION METHOD

The influence function methods (Figure 1) are based on the prognosis of the subsidence trough with the help of the influence area theory around the point of extraction [1], [10], [11]. These methods can be applied to the extracted areas of different forms, but they are more difficult to calibrate and verify than the profile function methods [13], [18].

These are methods used to determine the influence exerted at the surface by the partial elements of the extracted area.

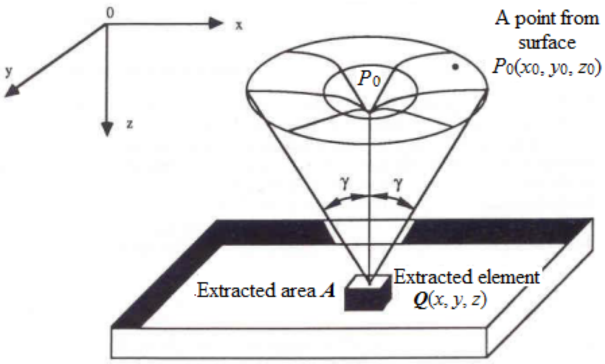

Fig. 1. *The influence of extracting the base element Q*

Different forms of influence functions were obtained by several researchers of subsidence events including - Bals 1932 Bayer, 1945; Sann 1949 Knothe 1957 Kochamanski 1957 Ehrhardt and Sauer 1961; Brauner 1973; Zich 1993, etc. [6], [15], [17].

In our case, for the surface deformation prognosis due to underground mining, the influence function method developed by Knothe (also known as Knothe-Budryk method) was applied.

This method is based on the Gaussian distribution of probabilities. According to this method, the math function is [10]:

$$k_z = \frac{1}{R^2}\left[e^{-\left(\frac{\pi x^2}{R^2}\right)}\right] \qquad (1)$$

3. ANALYSIS OF THE INFLUENCE OF THE CONCOMITANT UNDERGROUND MINING OF TWO SEAMS ON SURFACE

To analyze the behavior of the surface as a consequence of the simultaneous extraction of two coal seams, the influence function method was applied.

In order to study the influence of the underground mining of the two coal seams on the surface, two distinct situations were analyzed, namely:

- in the first situation it was considered that the distance (the elevation difference) between the two coal seams is constant and the gap between the two panels extracted on the two seams is gradually increased;
- in the second situation it was considered that the distance (the elevation difference) between the two coal seams is variable.

3.1. Analysis of the first case

In this case we considered the extraction of two horizontal coal seams of equal thickness (m = 10m), situated at a mining depth of 90m from each other, with a depth of extraction of the upper seam of 300m (Figure 2).

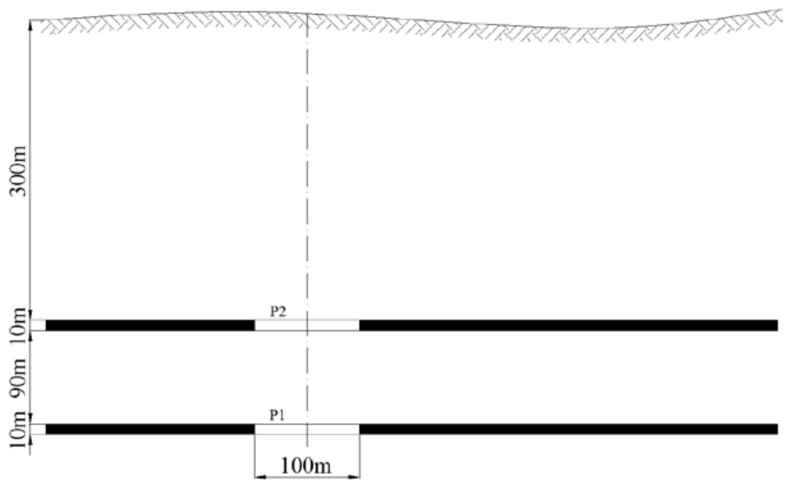

Fig. 2. *The influence of extracting the base element Q*

In this case, 11 different situations were analyzed. Thus, in the first situation, we considered that the panels P_1 and P_2 are extracted on the two seams, with sizes of 100m each, vertically arranged one above the other so that the centers of the two panels coincide (see Figure 2). For the other analyzed situations, the two panels were offset with 20m, reaching in the last situation, at a distance between the central points of the two panels of d = 200m (with a distance between the edges of the panels of x_a= 100m, Figure 3).

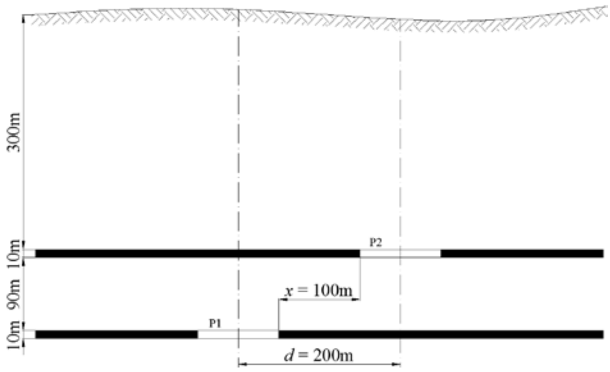

Fig. 3. *The position of the two panels for the last analyzed case*

The third dimension of the excavation has been chosen so as not to affect the way that surface moves in the area of interest.

Following the calculations performed, subsidence and horizontal displacement were predicted for all 11 studied situations.

Figure 4 shows the subsidence curves predicted by the influence function method and Figure 5 displays the predicted curves of horizontal displacement.

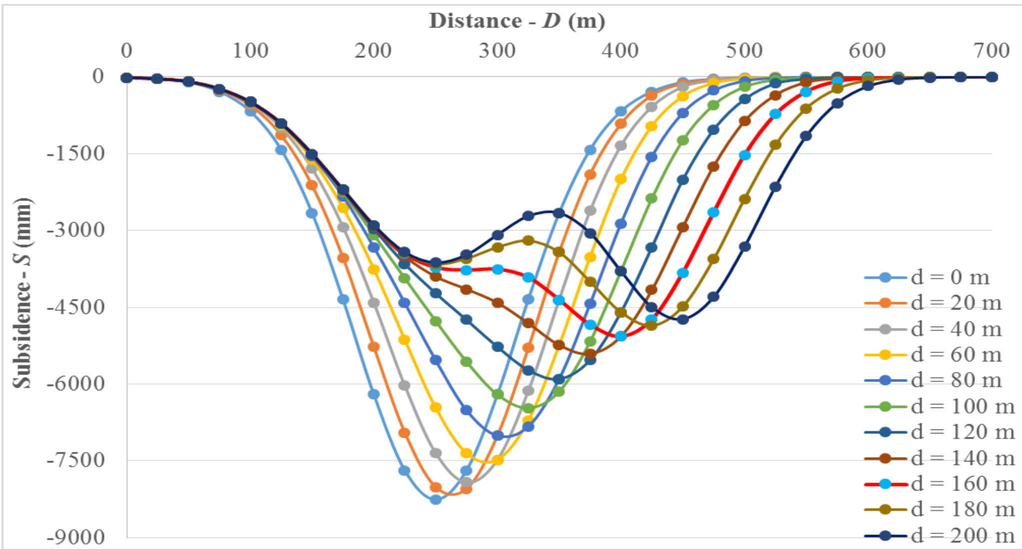

Fig. 4. *Subsidence curves predicted for the 11 studied situations – case 1*

The analysis of the predicted subsidence and horizontal displacement curves shows that the maximum subsidence and horizontal displacement decreases with the lag of the two panels, but the sizes of the subsidence trough are larger (the area affected by the underground mining is bigger).

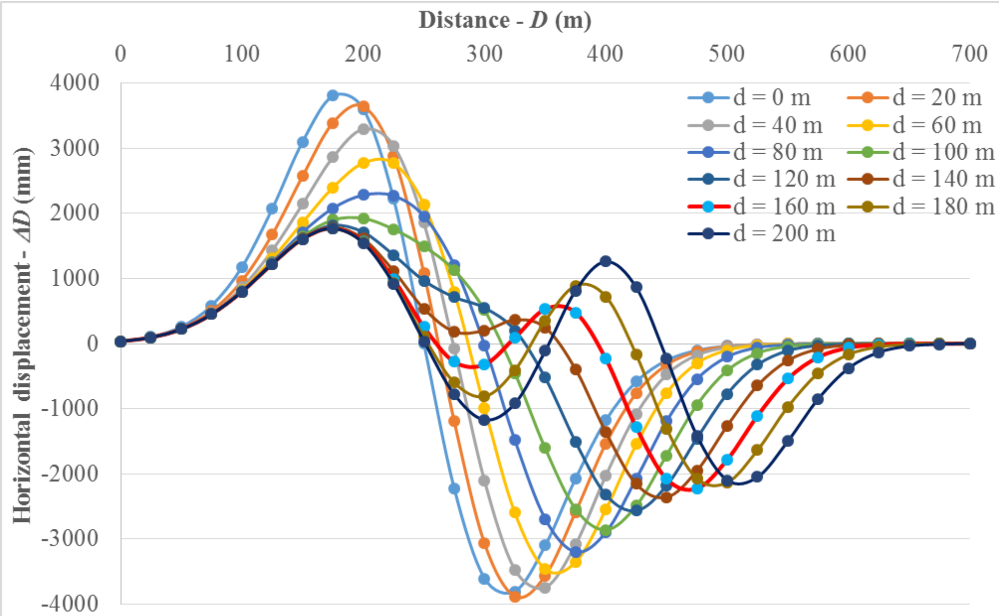

Fig. 5. *Horizontal displacement curves predicted for the 11 studied situations – case 1*

From the safety point of view of the buildings, it can be said that under the considered conditions, the ideal case is where the gap between the two panels is maintained at approximately d = 150-160m (namely x = 50-60m). In this case, we may observe that the subsidence in the central area of the subsidence trough is approximately constant and the horizontal displacement in this area is minimal, therefore the tensile and compressive stresses are minimal. For a better image of the surface movement, figures 6 and 7 show the subsidence and horizontal displacements, predicted for the case when d = 160m, in a 3D representation.

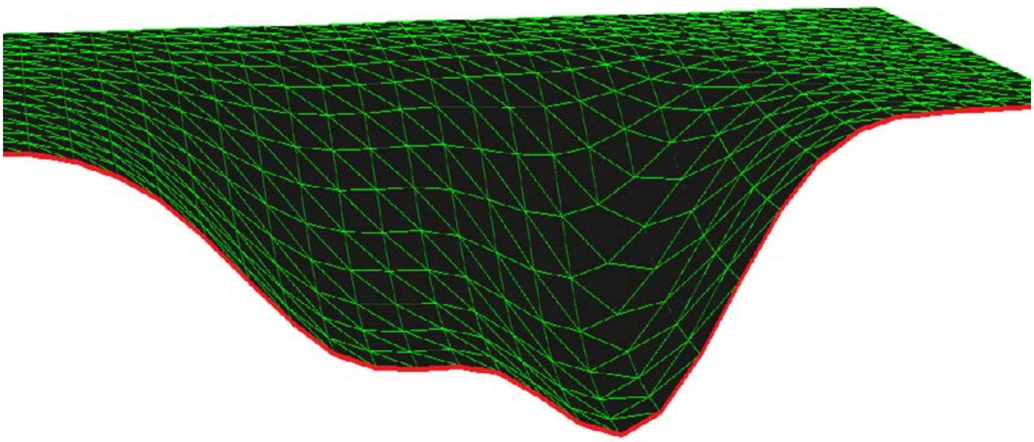

Fig. 6. *Predicted subsidence trough for the extraction of the two panels for d = 160m*

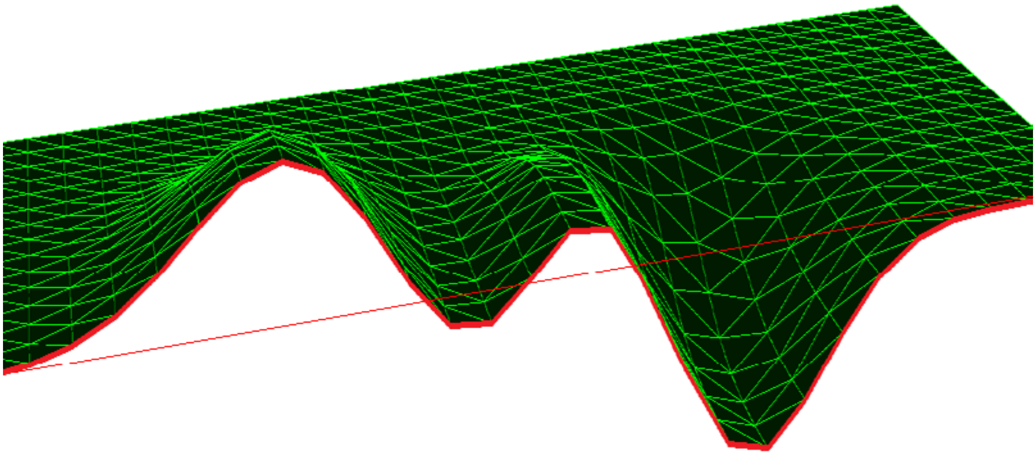

Fig. 7. *Predicted horizontal displacement for the extraction of the two panels for d = 160m*

3.2. Analysis of the second case

In the second analyzed case, was considered the extraction of two horizontal coal seams of equal thickness (m = 10m), located in the first situation analyzed at a depth of 50m from each other, with a mining depth of the upper seam of 300m. For the other analyzed situations, the difference in elevation between the two coal seams was gradually increased by 50 m, until a vertical distance between the two coal seams of 300 m was reached (Figure 8).

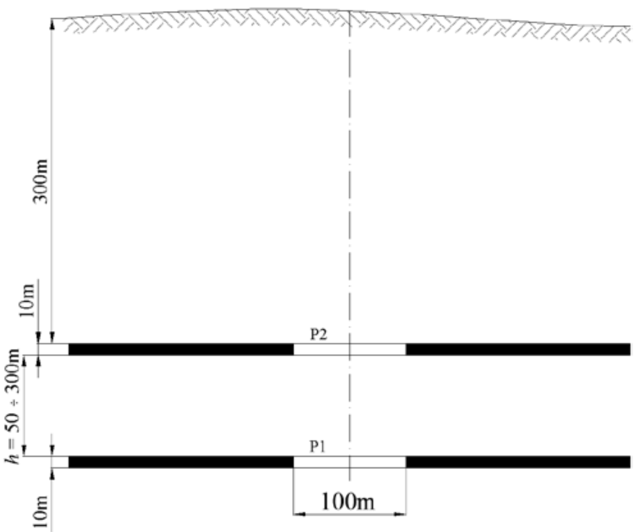

Fig. 8. *The influence of extracting the base element Q*

So, a total of 6 situations resulted, for each situation being determined the subsidence and horizontal displacement (graphically represented in figures 9 and 10).

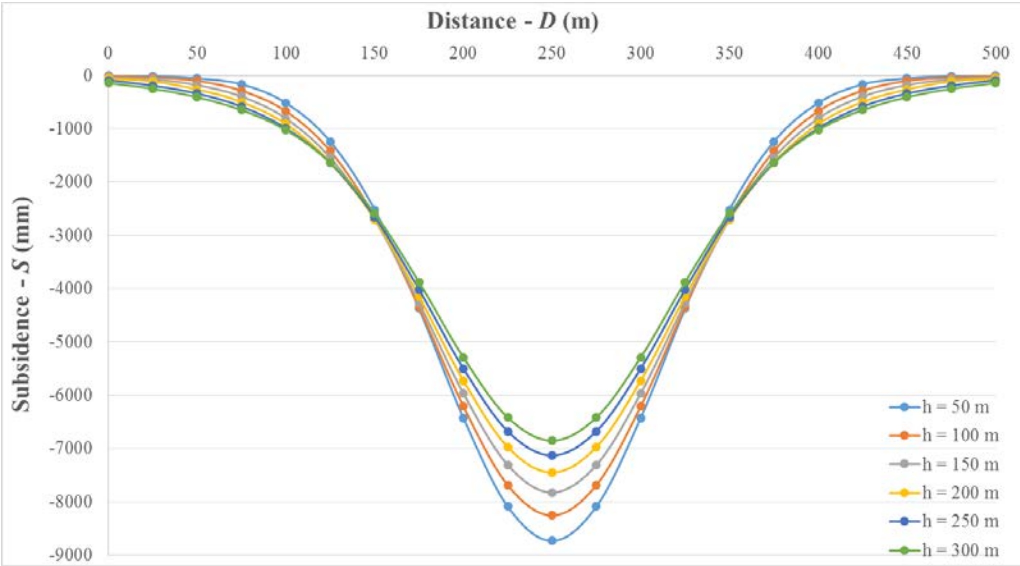

Fig. 9. *Subsidence curves predicted for the 6 studied situations – case 2*

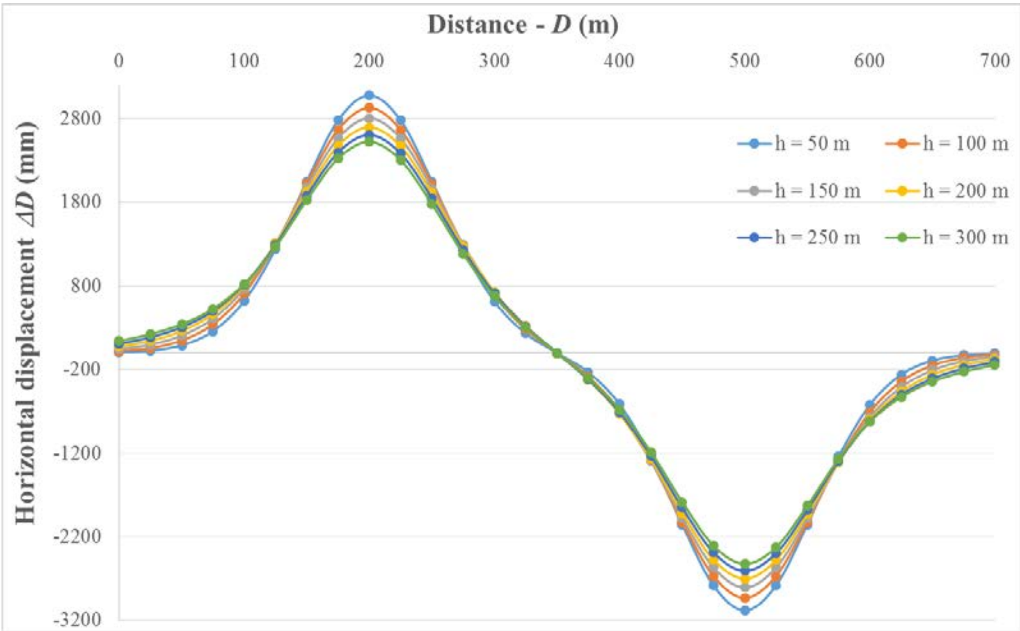

Fig. 10. *Horizontal displacement curves predicted for the 6 studied situations – case 2*

Analyzing the figures 9 and 10, it can be seen that both the maximum subsidence and the maximum horizontal displacement decrease significantly with the increase of the elevation difference between the two extracted coal seams. With regard to maximum subsidence, this is reduced by approx. 1900mm and maximum horizontal displacement of approx. 550mm.

The decrease of the maximum values of the subsidence and the horizontal displacement, with the increase of the elevation difference, takes place in a linear form. If between the first two situations (h = 50m and h = 100m) the difference between maximum subsidence is 476mm, and 150mm for horizontal displacement, between the last two situations (h = 250 and h = 300m) these differences have the values of 278mm for subsidence and 82mm for horizontal displacement.

4. CONCLUSIONS

The influence function method belongs to the empirical methods group applied for the prognosis of the surface deformation due to underground mining. Unlike the profile functions method, this method can be applied and operated in the case of several extracted areas, or in the case of the extracted areas with difficult configurations.

The applying of the influence function method in the case of the current paper resulted in an overview of the deformation of the surface as a result of underground mining of two panels, located on two horizontal coal seams. Two different cases have been studied:

- *in the first case* - it was considered that the distance (the elevation difference) between the two coal seams is constant and the gap between the two panels extracted on the two seams is gradually increased;
- *in the second case* - it was considered that the distance (the elevation difference) between the two coal seams is variable.

For the first case the two coal seams have an equal thickness (m = 10m), are placed at a depth of 90m apart, with a mining depth of the top seam of 300m.

To observe how the mutual position of the two panels influences the deformation of the surface, 11 situations were analyzed (in the first case the two panels are vertically arranged one above the other, and for the other situations the distance between the centers of the two panels was gradually increased with 20m for each case).

Analyzing the results obtained, we may assert that in all analyzed cases a common subsidence trough emerged at surface, resulted from the superposition of the effects of the two extracted panels. In the case when the distance between the two panels is wider (estimated to be approximately x = 200m), two subsidence troughs would result on the surface for the extraction of each panel.

It can also be seen that if the two panels are perfectly superimposed, subsidence reaches a maximum value of approx. 8200mm (for given conditions) and the horizontal displacement is approx. 400mm.

With the lag of the two panel centers, the maximum subsidence decreases, but the affected area is larger.

For the second case the difference in elevation between the two coal seams was variable, from h = 50m to h = 300m, the mining depth of the upper seam is 300m (constant in all cases) and the seams have a thickness of 10m.

It was found that the variation in the elevation difference between the two coal seams significantly influences the maximum subsidence and the maximum horizontal displacement, decreasing with the increase of the elevation difference. It can also be seen that the bigger the difference is, the larger is the subsidence trough.

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GENERATING THE DIGITAL TERRAIN MODEL BASED ON GOOGLE EARTH RESOURCES

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NICOLAE DIMA [2]

Abstract: *This paper presents a way of generating the digital terrain model based on available online resources (Google Earth). Thus, the work presents the working methods and the steps to be taken from the identification of the area of interest to the obtaining of the digital terrain model, a model with high analytical capacity. In the example given, the working methods have been applied with the purpose of generating the digital terrain model for the Ciungetu – Vâlcea area.*

Keywords: *DEM, DTM, TIN, Google Earth, ArcGIS, digital model, level curves*

1. OVERVIEW AND CONCEPTS

The rapid technological development of the last decade (especially in the fields of photogrammetry and remote sensing) has facilitated the diversification of topographic and photogrammetric data acquisition methods, which enables high quality digital products with minimal resources (material, financial, human) [6].

Starting from the current needs of society, one of the main digital products used in various fields is the Digital Terrain Model (DTM). Among the domains in which the Digital Terrain Model finds its applicability, we mention: the development of orthophotomaps and ortho-photographers, the analysis of telecommunication systems, the design of utility-urban networks, the design of transport networks, the use in geographic information systems, in different points / areas (aviation, hydrology) etc.

Depending on the terminology used, the perspective and the way the end-user understands and exploits the Digital Terrain Model, several similar concepts have emerged, but which have important differences at the technical level. Thus, we can identify:

The Digital Elevation Model (DEM) is a digital model based on an ordered network of points (usually a raster data structure) for which the X and the Y coordinates, as well as the elevation are known [1]. In DEM, the elevation is the height

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of the plot at a vertical datum without highlighting the coverage of the surfaces (vegetation, construction, etc.). Generating DEM is based on the principle of interpolation.

The Digital Terrain Model (DTM) is a DEM - like digital model, but it is distinguished by the fact that the arrangement of the points is irregular or random. Thus, it has the advantage that points density can be changed so that the land surface is rendered as faithfully as possible, and points of interest can be incorporated even if they do not follow a predefined pattern (a pre-set network) [1]. Obtaining a DTM implies a greater resource consumption compared to obtaining a DEM, but it is considered to be technically superior because it is more permissive in later exploitation.

The Triangular Irregular Network (TIN) is a way of representing the position and shape of the terrain. Using TIN, the land area is represented by the total of adjacent triangular surfaces without any overlap between them. The irregular triangular network is stored in vector data structures and based on it, relatively easy information can be extracted about the slope of the terrain and the level curves.

Level curves are isolated lines which link points with the same elevation (relative to a vertical datum). Level curves are a method of representing three-dimensional surfaces on a two-dimensional support. Although using level curves we make sure that the elevation information is included in the plan, they do not allow the computerized processing and analysis of this information so that it can be said that from the point of view of the exploitation they are inferior to the previously defined models (DEM, DTM, TIN).

In the present paper I have planned to present the working methods used for generating the digital terrain model and extracting the level curves for the Ciungetu – Vâlcea area using Google Earth resources. Thus, through the development of the work stages, I have planned to obtain the digital terrain model and the products derived from it in Stereographic Projection System 1970 (Stereo 70) and the Black Sea Altimetry System 1975.

2. RESOURCES AND WORKING METHODS

Schematically, the processes and activities carried out to achieve the objectives can be represented as follows:

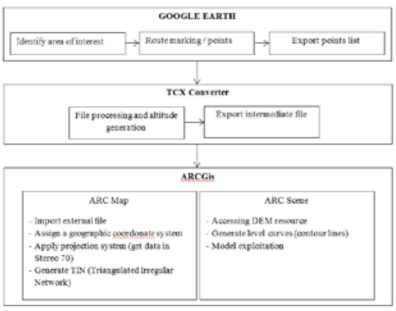

Fig. 1. Structuring the DTM generation process

In addition to the hardware resources, the following software resources were used to obtain the intended results:

- *Google Earth*: is a software product that provides 3D Earth representation, based on satellite imagery [2]. In this paper this software (available for free) was used to identify the area of interest, marking points that will be the generation of digital terrain model and export the list containing the geographical coordinates of these points;
- *TCX Converter*: is a software product that provides data conversion facilities in various types, particularly data types commonly used in surveying, remote sensing, geographic information systems, etc. Also, this software includes extraction features for altitude values according to latitude and longitude points;
- *ARCGis*: is a software package produced by ESRI that allows creation, processing, integration, analysis and display of geographic data at different levels. The ArcGIS suite of software is made up of various specialized modules, including: ArcMap, ArcCatalog, ArcScene. The ArcGIS for Desktop software version 10.3.1 was used to implement the case study. (short presentation at: http://www.esri.com/library/brochures/pdfs/arcgis-desktop.pdf).

2.1. Google Earth – Identifying the area of interest

The area of interest for the present work is the administrative boundaries of Ciungetu village, Malaia commune, Vâlcea County. I turned my attention to this area because the digital terrain model for this area can be exploited through several areas of activity:

- *Tourism*: Positioned in a touristic area and near the ski area of Transalpina Sky Resort, this village has experienced a sudden development, which has led to the construction of a significant number of boarding houses. Thus, a digital model of land is a real help both in the design of new constructions and the local authority for the proper management of expert opinions.
- *Urbanism and utility-urban structures*: the digital terrain model can be exploited by the local authorities' specialists for the planning and execution of the specialized works.
- *Hydrology and hazard scenarios*: given that Lotru-Ciunget (the most productive hydro power plant located on the Romanian inner rivers) is located on the territory of this village, and upstream there are several storage dams

serving this hydroelectric power plant, the digital terrain model can be successfully exploited to run hazard scenarios (dam breaking).

In Google Earth, area identification can be done both directly and by importing files that contain area delimitation information (e.g.: .shp, .kml, etc.). In the case study, the area was identified and marked by importing a .shp file (a file obtained from the exploitation of an existing geographic information system).

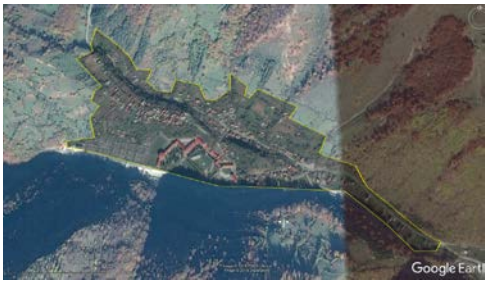

Fig. 2. Identifying and determining the area of interest – Ciungetu

Fig. 3. Marking the area

The area under the present work (Ciungetu) has an area of 46.4 ha and a perimeter of 4.81 km.

2.2. Google Earth - Route / Points Markup

Once the area of interest has been identified, the next step was to mark the points that would form the basis for generating the digital terrain model. In Google Earth, this is done by adding a path (Add -> Path), at which time the user has the ability to set route representation parameters (style, color, units of measurement, etc.).

Starting with the definition of the DEM and DTM concepts, the actual markings of the points were made. Thus, as required, they can be arranged in matrix form (thus ensuring a uniform representation of the plot) or arranged in a random manner (with the advantage that additional points of interest may be marked, but also the disadvantage that points key can be omitted to generating the digital model (especially inflection points)). Layout of points randomly has the advantage of reduced time consumption, but their matrix layout has the advantage of a better control over their layout and density.

In the present paper we have opted for the matrix arrangement of the points, trying to observe the following parameters: horizontal layout of 35 – 50 m and vertical layout of 25 – 35 m. Thus, we created the marking of

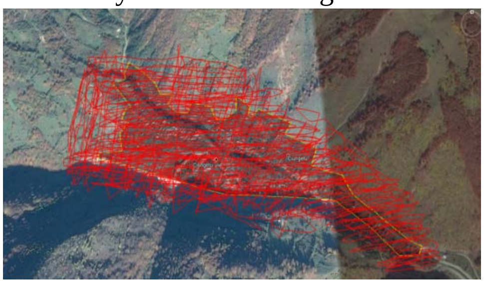

Fig. 5. Adding route – random layout of the points

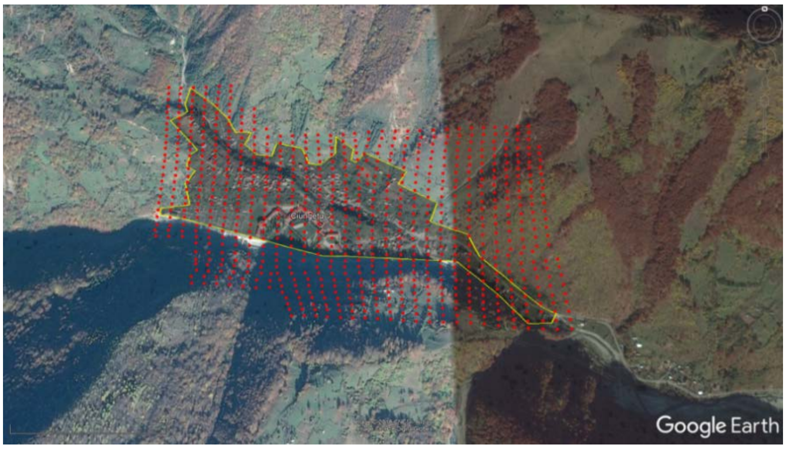

Fig. 6. Marked points layout

831 points for which the geographical coordinates are known.

Note: the route shown in “Figure 5. Add route – random layout of points” contains 2965 points, with a time consumption about 10 times smaller than the route shown in “Figure 4. Add route – matrix layout” (with 831 marked points). Thus, the density of the marked points is much higher, but their layout is not known, which means that the final product parameters (DTM) cannot be estimated.

Note: because the information is extracted from Google Earth, the coordinates of the marked points are geographic coordinates (WGS84 coordinate system), which means they will later be transformed into plane coordinates.

Generating the digital terrain model depends on how the data is acquired, how the appropriate interpolation method is chosen, and how data structures are represented [7]. In the case study presented, DTM generation is based on getting a continuous surface by applying interpolations to data extracted from Google Earth.

2.3. Google Earth - Export points list

Exporting the list of points marked in Google Earth (and associated geographic coordinates) is done by accessing the “Save Place As ...” option and selecting the destination of the file. The file so obtained is .kml.

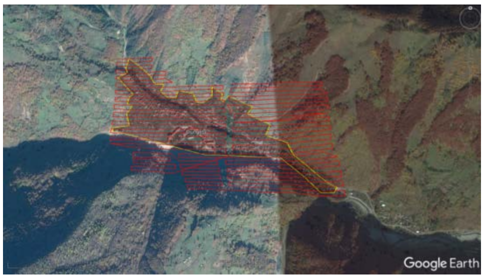

Fig. 4. Adding route – matrix layout of the points

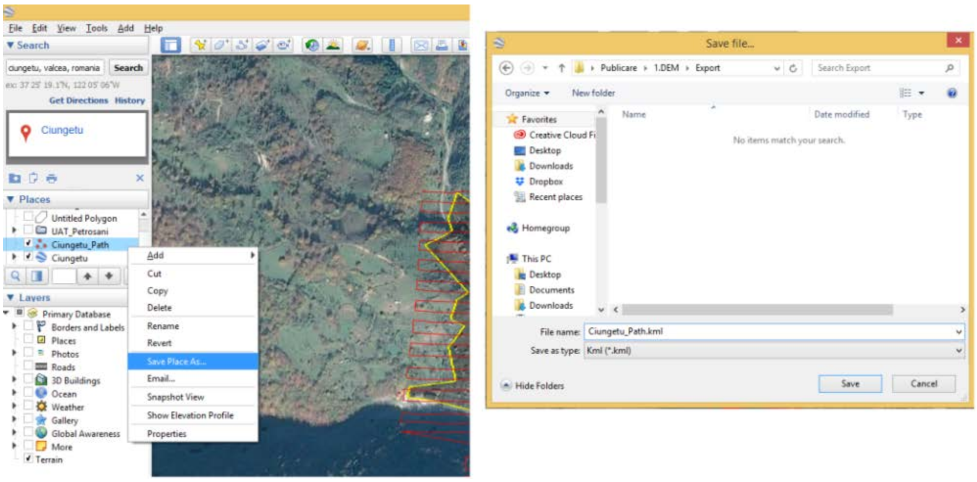

Fig. 7. Export marked points list

UNIX TIME	TIME	LAT	LONG	ALT	DIST	HR	CAD	TEMP	POWER
1178690400	2007-05-09T06:00:00Z	45.391829	23.939542	723	0	0	0	No Data	No Data
1178690405	2007-05-09T06:00:05Z	45.391892	23.939781	698	0.0200387	0	0	No Data	No Data
1178690408	2007-05-09T06:00:08Z	45.391936	23.939934	698	0.0330241	0	0	No Data	No Data
1178690411	2007-05-09T06:00:11Z	45.391981	23.940087	698	0.0460626	0	0	No Data	No Data
1178690415	2007-05-09T06:00:15Z	45.392022	23.940297	698	0.0631885	0	0	No Data	No Data
1178690420	2007-05-09T06:00:20Z	45.392091	23.94054	670	0.0837821	0	0	No Data	No Data
1178690425	2007-05-09T06:00:25Z	45.392171	23.940787	674	0.105128	0	0	No Data	No Data
1178690433	2007-05-09T06:00:33Z	45.39228	23.941144	674	0.135633	0	0	No Data	No Data
1178690441	2007-05-09T06:00:41Z	45.392382	23.94158	647	0.1715917	0	0	No Data	No Data
1178690449	2007-05-09T06:00:49Z	45.392415	23.942015	647	0.2058713	0	0	No Data	No Data
1178690453	2007-05-09T06:00:53Z	45.392372	23.942177	655	0.2194472	0	0	No Data	No Data

Fig. 8. Exported file structure

2.3. TCX Converter – File Processing, Altitude Generation and Intermediate File Export

Using the TCX Converter software, the user open the previously exported file (Open File ...) and update the altitude (Update Altitude) based on the resources available online. Updating altitudes can also be achieved by using other online resources such as http://www.gpsvisualizer.com/elevation.

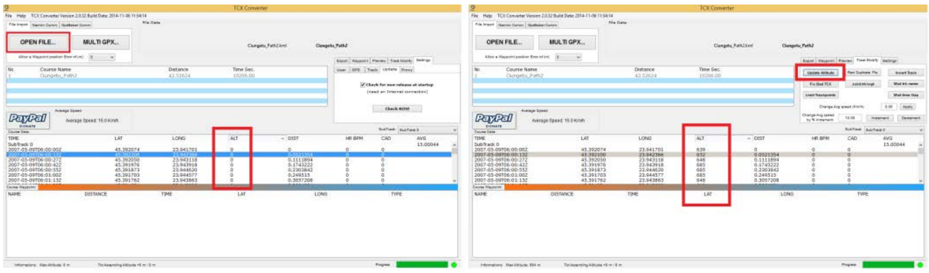

Fig. 9. Updating altitudes

Note: The TCX Converter has a number of parameters (control points, maximum deviations, etc.) that can be configured as needed, with direct influence on the accuracy of the updated data (altitudes).

The information thus obtained can be exported (Save CSV File ...) to a .csv file, which will be downloaded for further processing in ArcGIS. The resulting file will contain more information than needed to generate the digital terrain model, which can be removed or ignored.

2.5. ARCGis – ARCMap/ARCScene

ArcMap is the main component of ArcGIS developed by ESRI and is primarily used for viewing, editing, creating and analyzing geospatial data. ArcMap offers users the tools to exploit data sets, use symbols, and create themed maps [3].

ArcScene is a component of ArcGIS that provides users with perspective viewing features of scenes / scenarios and direct interaction with data within the geographic information system. ArcScene is the main component of the 3D analysis system [4].

Generating the digital terrain model based on Google Earth's marked and extracted points is accomplished by completing the following steps:

- *Retrieving (importing) the list of marked points (with geographic coordinates attached and altitudes generated in the previous step*)

Using ArcMap, the “Add Data ...” option is selected and the source file is selected, at which time a new thematic layer is automatically added, but no data is displayed in the window. To display data in the work area, starting from the created theme layer, the “Display XY Data ...” option is accessed and the fields corresponding to the representation mode are selected: X, Y, Z.

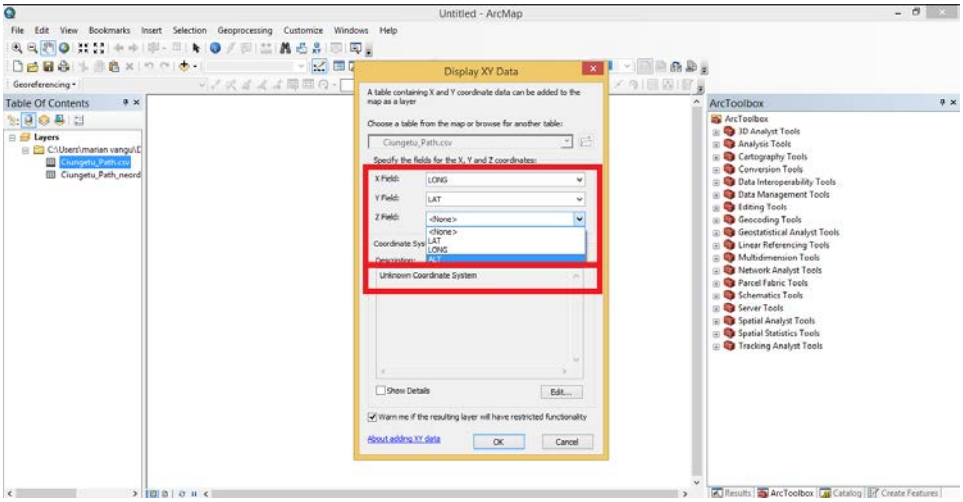

Fig. 10. Selcting the representation data used in the workspace

At this point, we can notice that the data set does not have a coordinate system attached, which will only be attached after saving the shape data set in ArcCatalog (the ArcGIS data collection). Upon completion of these operations, the points contained in the data set are displayed in the work window. To save the thematic layer as a permanent resource (usually in the default, personal or project database) that can be retrieved later, the option “Data -> Export Data ...” is selected and then the destination and type of data are selected (Shapefile in our case study).

- *Assigning the coordinate system*

After having saved this resource, it is necessary to assign the coordinate system to ensure the correctness of future exploitation. Since this resource was generated based on information extracted from Google Earth, the generated coordinate system should be WGS84 (originating system). Assigning the coordinate system is done by locating the resource in ArcCatalog and accessing the “Properties ...” option. Within the open window, you can select and attach the desired coordinate system (WGS84), at which time you can see various details of the date underlying the coordinate system.

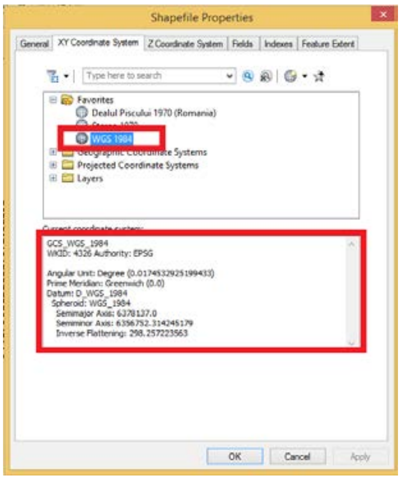

Fig. 11. Assigning the WGS84 coordinate system

- *Application of projection system and data acquisition in Stereo 70 system*

Since the resources used have been assigned WGS84 coordinate system and the results have to be in national system (Stereo 70) it is necessary to apply the projection parameters according to this system. This is done by running the “Project” command within the ArcToolbox functionality. Thus, it is necessary to select the primary resource assigned to the WGS84 coordinate system (at which time ArcMap already knows the assigned system), selecting the name and destination for the new resource (by applying the projection parameters, a new resource is created, retaining the unchanged resource projecting) and selecting the new coordinate system (Stereo 70).

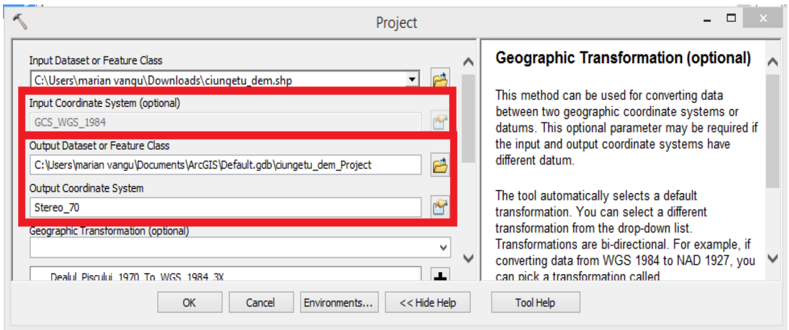

Fig. 12. Running the “Project” command for projecting the resource in the Stereo 70 coordinate system

After running the command, the new resource will be displayed in the workspace, and it can be noticed that the coordinate system and the metric system have been assigned.

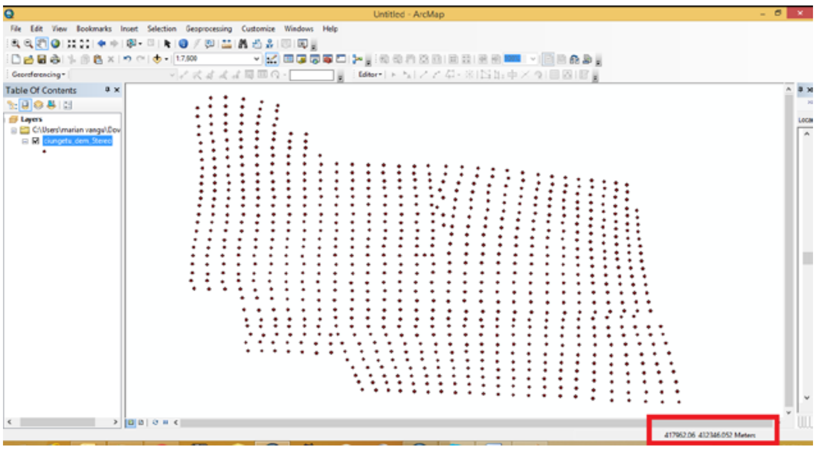

Fig. 13. Displaying the resource in the workspace, with attributed coordinate and metric systems

- *Generating TIN (Triangulated Irregular Network)*

Given that this paper aims to obtain digital products to allow further analysis, it is necessary to generate TIN (a data structure that offers a high degree of flexibility in operation). Triangular irregular networks used for surface modeling should be generated using designed coordinate systems. Geographic coordinates are not recommended because triangulation cannot be guaranteed when X and Y coordinates are expressed in angles, and distance based calculations such as slope, volume, horizon line can lead to incorrect results [5].

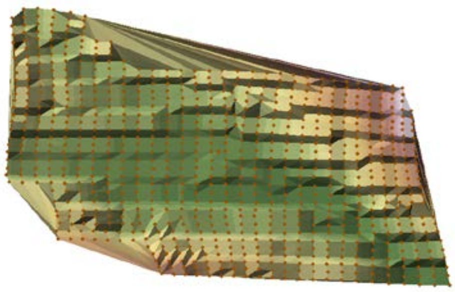

Fig. 14. Displaying TIN in the workspace (2D representation)

Generating TIN is done by running the "Create TIN" command in ArcToolbox's (3D Analyst Tools -> Data Management -> TIN -> Create TIN) functionality. Running this command requires selecting the rescue location, co-ordinate system and selecting the field containing the associated altitudes. After running the command, the new resource (TIN) in the 2D representation will be displayed in the workspace.

- *3D exploiting of the digital model*

ArcScene is used to exploit 3D of the generated digital model. Within this component the user has the possibility to dynamically exploit the model: generate thematic models for which different parameters can be configured, level curve viewing, TIN network viewing, mesh view, elevation view, slope view etc.

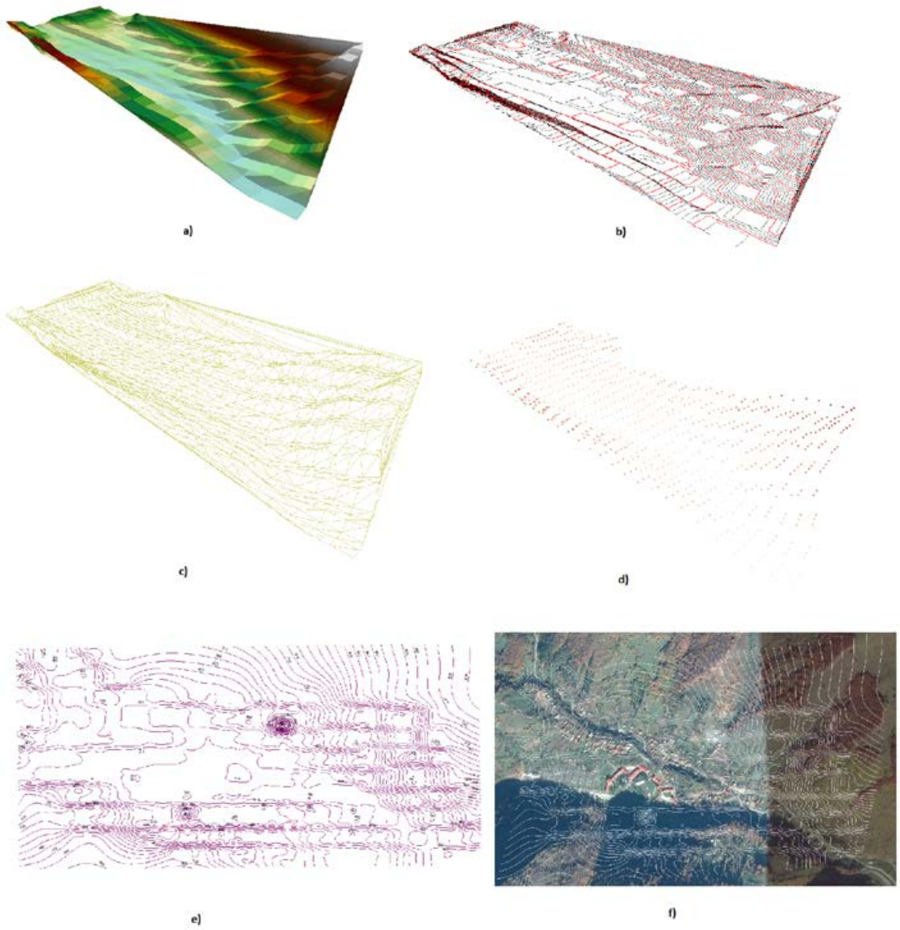

Fig. 15. Digital model exploitation: a) elevation pattern, b) 3D representation level curves, c) edge representation, d) elevation points, e) plane level curves, f) superimposed level curves in Google Earth

CONCLUSIONS

Given the recent technological developments as well as the diversity of digital resources (photogrammetric resources, satellite images, maps and digital plans, etc.) that can be accessed quickly, it is now possible to easily generate digital products such as orthophotomaps or even three-dimensional representations of the terrain.

By using and processing the available digital resources, digital terrain models can be generated and can be used for analytical purposes in various areas: topography, cadastre, urban planning, urban network design and execution, hazard scenarios, etc. Thus, by using specialized software, both specialized personnel and inexperienced users have the opportunity to exploit the digital terrain model: extract various thematic information (level curves, elevation model, elevation points, etc.) and carry out three-dimensional analyzes.

In the present paper we presented the methods of acquisition and processing of digital data and generation of the digital model of land, a model based on which useful analyzes can be made in various fields of activity.

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THE DEVELOPMENT OF MINERAL TRIANGULATION NETWORKS USING A SIMPLIFIED CALCULATION PROCESS

OFELIA-LARISA FILIP [1]

Abstract: The procedure referes to dependent triangulation networks, and cosists in the simultaneous utilization of the theory of indirect measurements and conditioned measurements. The use of indirect measurement theory and conditional measurements means a low volume of computation completed by simple matrix relations applied convincingly in practice. In order to reduce the processing of the measured quantities, there is still a process in which the theory of the indirect measurements and the theory of the conditioned measurements are applied to the dependent triangulation networks, very frequent networks encountered in the mining basins. Thus, with regard to the mining domain, it follows that triangulation networks play a decisive role in the good development of topographic activity through which multiple mining problems are solved. The specificity of triangulation networks in support of the overall mining activity is that they develop on surfaces corresponding to mining basins. The form of these mining triangulation networks as well as the density of the points forming them depends on the shape of the mining basin, the number and position of the mining operations within the basin.

Keywords: *Mining surveying, topographic underground networks, errors, topographic measurements*

1. INTRODUCTION

It is known that the purpose of triangulation networks is to determine on a certain surface and plurality of points of a certain density.

These fixed points will continue to constitute support and control points for the set of topographic works developed according to the nature of the construction works (industrial, civil, communication, mining, etc.) which it serves to achieve and their tracking over time (Dima, 2005b).

Regarding the way of determining the triangulation points in such networks it is specified that they can result from the accumulation of the order of I, II or III geodetic points, obtaining points of order IV and V or by solving dependent triangulation networks.

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The two methods for determining triangulation points have different theories to support the measurement of measured quantities. It is the theory of indirect measurements applied to the determination of points by framing and the theory of conditional measurements applied to the determination of points by independent triangulations (Dima, 1997, 1999).

We consider the dependent triangulation network formed by the old points (whose coordinates are known) A, B, C, D, E, F and new points P1, P2, Q, S (the coordinates of which are to be determined) (fig. 1).

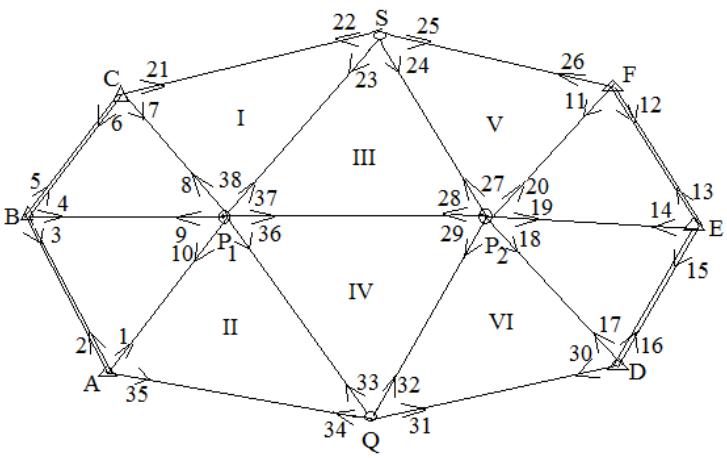

Fig. 1. Triangulation network

By abandoning the processing of the measured magnitudes, according to the theory of conditional measurements applied to the triangulation network, as a whole it was envisaged, (Dima, 2005a):

- In the peripheral areas using the old points A, B, C, D, E, F apply the theory of indirect measurements.
- In the triangles I, II, ..., VI, respectively in the central area of the triangulation to apply the theory of conditional measurements.

According to this process there is obtained:

$$\begin{aligned} a_1\Delta x_1 + b_1\Delta y_1 - \Delta z_A + l_1 &= v_1 \\ -\Delta z_A + l_2 &= v_2 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ C_{20}\Delta x_2 + d_{20}\Delta y_2 - \Delta z_{P_2} + l_{20} &= v_{20} \end{aligned} \quad (1)$$

By eliminating the unknown Δz the following equivalent system is obtained:

$$A_1\Delta x_1 + \mathrm{B}_1\Delta y_1 + l_1 = v_1$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$C_{20}\Delta x_2 + D_{20}\Delta y_2 + l_{20} = v_{20}$$

Or:

$$\begin{aligned} &v_1 \quad +A_1\Delta x_1 + B_1\Delta y_1 \quad +l_1 = 0 \\ &v_2 \quad +A_2\Delta x_1 + B_2\Delta y_1 \quad +l_2 = 0 \\ &v_{20} \quad +C_{20}\Delta x_2 + D_{20}\Delta y_2 + l_{20} = 0 \end{aligned} \tag{2}$$

To which the system is added:

$$\begin{aligned} &v_7 - v_8 - v_{21} + v_{22} - v_{23} + v_{38} + \omega_I = 0 \\ &-v_1 + v_{10} + v_{38} - v_{36} + v_{33} - v_{34} + \omega_{II} = 0 \\ &v_{23} - v_{24} + v_{27} - v_{28} + v_{37} - v_{38} + \omega_{III} = 0 \\ &v_{28} - v_{29} + v_{32} - v_{33} + v_{36} - v_{37} + \omega_{IV} = 0 \\ &-v_{11} + v_{20} + v_{24} - v_{25} + v_{26} - v_{27} + \omega_V = 0 \\ &v_{17} - v_{18} + v_{29} - v_{30} + v_{31} - v_{32} + \omega_{VI} = 0 \end{aligned} \tag{3}$$

The system consisting of literary (2) and (3) literary is written:

$$\begin{aligned} &a_1v_1 + \cdots + a_{38}v_{38} + A_1\Delta x_1 + B_1\Delta y_1 + C_1\Delta x_2 + D_1\Delta y_2 + l_1 = 0 \\ &b_1v_1 + \cdots + b_{38}v_{38} + A_2\Delta x_1 + B_2\Delta y_1 + C_2\Delta x_2 + D_2\Delta y_2 + l_{20} = 0 \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &r_1v_1 + \cdots + r_{38}v_{38} + A_r\Delta x_1 + B_r\Delta y_1 + C_r\Delta x_2 + D_r\Delta y_2 + \omega_{IV} = 0 \end{aligned} \tag{4}$$

Number of equations:

$$r = 20 + 6 = 26$$

The number of unknowns:

$$n = 38 + 4 = 42$$

Or the matrix has the form:

$$av + Ax + \omega = 0 \tag{5}$$

The following is added to the system (5):

$$F = v'v - 2K'(av + Ax + \omega) = min$$

The minimum condition leads to the system:

$$\frac{\partial F}{\partial v} = 2v - 2A'K = 0$$
$$\frac{\partial F}{\partial x} = 2A'K = 0$$

Where from:

$$v = a'K = 0 \qquad (6)$$
$$A'K = 0$$

With relations (6) the system (5) becomes:

$$aa'K + Ax + \omega = 0$$
$$A'K = 0 \qquad (7)$$

By solving the system of normal equations (7) it follows:

$$K = -(aa')^{-1}(Ax + \omega)$$

and as a consequence:

$$x = -[A'\,(aa')^{-1}A]^{-1}A'\,(aa')^{-1}\omega \qquad (8)$$

With the values of the matrix x the correction matrix v is obtained with the equality:

$$v = -a'(aa')^{-1}(Ax + \omega) \qquad (9)$$

Note:

The calculation volume is reduced if the expressions of corrections in the equation system (2) are introduced into the equation system (3) (Dima, 2014).

A system is obtained with:

-6 equations
-34 unknown

3. CONCLUSIONS

The work was done on the basis of how to define such mining triangulation networks and their importance in solving the problems of elevation and topographic plotting in a unitary way, for multiple fields of activity, including the exploitation of useful minerals through underground mining works and up-to-date.

The processing of the measured quantities in order to determine the corrections on the directions and the corrections on the coordinates of the points P1 and P2 with the simultaneous use of the theory of the conditional measurements and the theory of the indirect measurements requires a small volume of calculation to obtain a system consisting of 6 equations.

The use of matrix calculation methods in defining the theoretical background of the problem has led to easy obtaining simple matrix relations with direct and convenient applicability in the practical processing of measurements.

I mention that the presented analyzes use the matricial calculation with which the form of the error equations systems of the systems of normal equations and the determination of the probable values with the corresponding precisions are adaptable to the computer system.

It is possible to evaluate the clearing afterwards.

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VISUAL ANALYSIS OF DEFORMATIONS FROM THE QUARRY AND INNER DUMP STEPS FROM NORTH PESTEANA MINING PERIMETER

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MARIA LAZAR [2]
FLORIN FAUR [3]

Abstract: Deformations and changes occurring in a rock mass, whether natural or anthropic, result from the geotechnical characteristics of the rocks and the influence of various external or internal factors. Under the influence of external factors, such as vibrations, overloads, the presence of groundwater or surface water, there results deformations and changes such as cracks, fissures, erosion and sufosis phenomenon, compaction, superficial or deep landslides etc. These types of deformations and changes signal the possibility of occurrence of negative geotechnical phenomena, such as landslides, which endanger the safety of people and objectives in the zones of influence. Also, these changes can influence the stability of the individual steps and even of the systems of steps, which is why it is necessary to constantly monitor and evaluate the stability in order to carry out the safety of the working operations. In this paper, a visual analysis is performed in order to identify deformations occurring in the North Pesteana mining perimeter and to highlight the possible problems that may arise in terms of stability of the quarries and the safety of the employees and objectives of the areas of influence.

Keywords: *visual analysis, deformations, landslide, quarry, inner dump, stability*

1. INTRODUCTION. THE IMPORTANCE OF VISUAL ANALYSIS IN SLOPES STABILITY

The visual analysis of the deformations and changes occurring in a rock mass/rock deposit is an important step in the land stability assessment activity. Based on this, areas with potential risk are identified deformations, changes, possible causes and other related effects are highlighted.

The presence of discontinuities, such as fissure, cracks, fissures, stratification, etc., and changes resulting from surface erosion, sufosis or sliding phenomena, affect the strength characteristics of rocks and, implicitly, massifs of rocks (Rotunjanu, 2005).

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Unlike faults that are large-scale tectonic discontinuities, cracks and fissures are small-scale discontinuities. As an extension they may vary from a few centimeters to tens of meters and may have an opening up to a few tens of centimeters. Cracks and fissures can cause the massive fragmentation of the masses and reduce the resistance of rocks and rock massifs (Rotunjanu, 2005).

Deformations and changes occurring in a massive of rocks are the result of alteration of the rocks understood as worsening of geotechnical characteristics under the influence of external or internal factors.

There are two types of alterations: superficial and deep. This paper focuses on the physical alteration of rock or its disintegration over time under the influence of various external or internal factors.

Surface alteration affects the rocks that constitute the superficial layer of rocks and is manifested by the permanent influence of external and internal factors: water, air, climate, organisms and gravity. Unlike this, the deep alteration is manifested under the action of the tectonic forces. The tectonics and micro tectonics of rock massifs are one of the main causes of landslides as a result of the reduction of the strength of the rock massive (Rotunjanu, 2005).

Erosion is the dislocation and entrainment of material on land surfaces. Erosion can be pluvial or windy and manifest, as the name says, under the action of waters or wind, plus the influence of gravity. Rainwater erosion is the main form of erosion that is emphasized in the present case, since surface water leakage, depending on local conditions (rainfall, infiltration capacity, slope angle, water flow speed etc.) can determine the appearance of gullies (up to 30 cm deep) and small to large ravines (with depths of up to several meters) (Lazăr, 2010). The appearance of gullies and ravines are considered as being the primary processes of the landslides (Lazăr et al., 2012).

Landslides are superficial or depth displacements of the rocks on the slopes of rocks massifs. Landslides are the most frequent and dangerous forms of degradation of rock massifs and, most of the time, are signaled by the deformations and changes described in this paper.

Therefore, the first part of the paper shows the importance of performing visual analyzes, which is why a case study for the mining perimeter of North Pesteana quarry was carried out.

2. LOCATION OF THE OBJECTIVE

The perimeter of North Pesteana quarry is administratively owned by Gorj County, being located within the Urdari and Balteni communes. The North Pesteana quarry was opened in the area where the Jiu River bedside existed prior to its regularization, and includes the Jiu meadow about 2 km wide, with odds of +137 m ÷ +155 m, inclined to the east, towards the Jiu river bed and to the south.

In the mining perimeter of North Pesteana quarry, both excavation and sterile dumping are carried out in 4 steps.

Taking into account that the mining perimeter is still in operation (for the next 6 years), this indicates that with the advancement of the working front and extension of the inner dump, there will always be new deformations and changes within the perimeter that may favor the occurrence of negative geotechnical phenomena.

3. RESEARCH AND SITE OBSERVATIONS

In order to be able to characterize the technical state of the internal dump and the in situ steps of the North Pesteana quarry, several field visits were carried out between April 2017 and June 2018. At the same time, these visits were aimed at collecting data and information on the geometrical and geotechnical characteristics of the rocks in the perimeter, the eventual sliding (superficial or profound) phenomena that occurred over time and their causes. (Apostu, 2018)

As a result of the visual analyzes carried out, and also on the basis of the information received, regarding the technical state of the quarry and of the inner dump, we will continue to list a number of observed aspects.

As a result of periods of excessive precipitation and of the periods of snow melting, there were some superficial landslides both on the in-situ slopes (Fig. 1.a) and on the inner dump slopes. The reason for these slides is the increase of the humidity of the rocks and, implicitly, of the volumetric weight, which leads to a decrease of the stability reserve.

Numerous erosion zones have been highlighted - generally, gullies (Fig. 1.b), so small ditches - formed as a result of the superficial water flow.

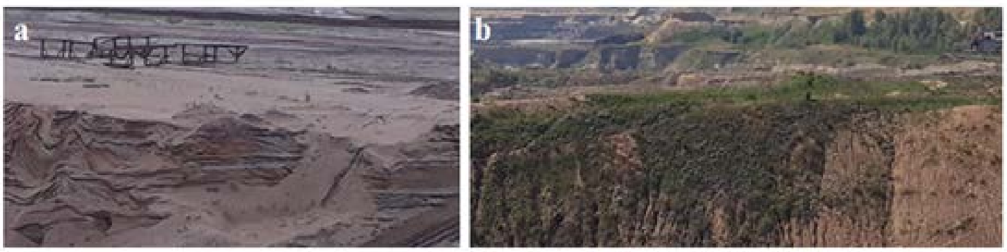

Fig. 1. (a) Superficial landslide on in-situ slope; (b) Gullies on inner dump slope;

As a result of the fact that the dewatering of the aquifer formations is realized naturally through the slopes of the quarry, the sufosis phenomenon was manifested, which led to the occurrence of sufosis zones on the slopes of the steps I (Fig. 2.a) and II. In the case of natural drainage of groundwater, there is continuous entrainment of the fine particles of rocks, which leads to the occurrence of these sufosis zones, basically underground gaps, of different dimensions and at different depths.

As a result of erosion by sufosis, depending on the depth at which the underground gap is formed and its size, can cause collapse of the rocks as a result of loss of rock stability from the roof of the gap.

Recently (at the beginning of 2018), on the eastern slope of the quarry there was a landslide, which affected the structure of the road that serves the mining perimeter (Fig. 2.b). The causes of this landslide were the abundant precipitation and the major infiltrations from the Jiu River.

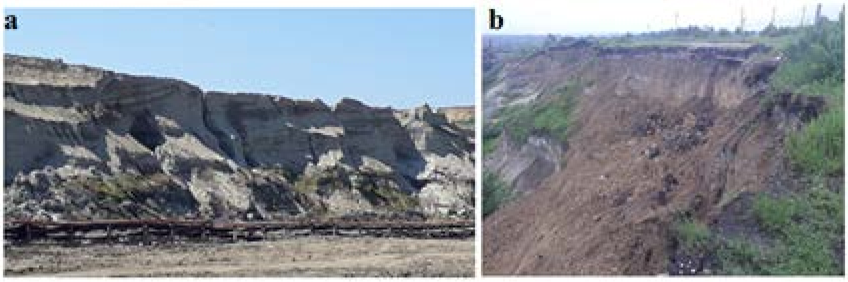

Fig. 2. (a) Sufosis zones on the first step of the quarry;
(b) Landslide on the eastern slope of the quarry

On the berms of the inner dump steps there were fissures and tension cracks (Fig. 3). Although these changes can be attributed to longer periods without rainfall, they generally signal the possibility of occurrence of the landslides, so it is recommended to follow these types of changes.

Fig. 3. Cracks on the berm of second step of the inner dump

Analyzing the situation plans, it has been observed that there are some differences between the projected geometry and the existing one, both in the steps of the inner dump and in the steps of the quarry. These differences generally occur at the slope angles and less at the height of the steps.

The values of the slope angles exceed the maximum values established in the project of 18 - 27° for the individual slopes of the dump, respectively 4 ° for the individual slopes of the quarry. It has been observed that sterile material is deposited in the dump on a natural slope angle, the value of which varies depending on the nature of the rock, reaching in many cases up to 45 - 50° (Fig. 4.a). As a result of the applied methods of exploitation and of the used equipment, the slope angle for the pitches reaches values of up to 60 - 75° or even higher (Fig. 4.b). It was found from one visit to another that the practice of reducing the inclination of the slopes is not applied, most probably on the fact that the working front, respectively the inner dump, is advancing continuously, so the steps with this geometry have short service life.

Fig. 4. Inclination of the slopes of the quarry and inner dump during the exploitation period; (a) Inner dump; (b) Quarry

It has been noticed that with the advancement of work fronts and the expansion of the inner dump, these deformations are remedied, but new changes arise that signal the reduction of the stability reserve and the possibility of occurrence of negative geotechnical phenomena under the continuous influence of external and internal factors.

4. MEASURES TO REDUCE THE RISK OF LANDSLIDE

Generally, these deformations and changes can't be prevented. As these cause the worsening of geotechnical characteristics of the rocks and signal the possibility of occurrence of negative geotechnical phenomena such as landslides, it is recommended to apply local measures to increase the resistance of rocks after their occurrence. Some of the measures that can be recommended for the North Pesteana quarry are:

- removal of gullies, ravines, fissures and cracks by material filling, leveling and compacting;
- proper management of groundwater and surface water;
- applying measures to reduce the amount of infiltrated water from the Jiu River to North Pesteana quarry by reducing the permeability of the right bank of the Jiu River;
- reducing the amount of water that drains naturally through the slopes of the quarry or reducing the rate of infiltration by increasing the flow of dewatering in order to prevent the phenomenon of sufosis;
- respecting the projected values of the geometrical elements of the quarry and inner dump steps. Failure to comply with the projected values may favor the occurrence of negative geotechnical phenomena.
- performing visual and geotechnical analyzes, where appropriate, and intervening as quickly as possible to prevent these phenomena from occurring on a larger scale.

According to the literature, the determination of the contours of the working slopes and of the final slopes must take into account a number of criteria, such as the economic and social importance of the objective and the time of their stagnation. Thus, for small service times, such as for working slopes in a mining perimeter, lower stability factors are acceptable, on the grounds that they are remedied as work advances, but for very long service life times, for the definitive slopes, the value of the stability reserve must be high. (Fodor, 1980; Rotunjanu, 2005)

5. CONCLUSIONS

The visual analysis allows the highlighting of the deformations and changes that may indicate the possibility of occurrence of negative geotechnical phenomena. Based on the visual analysis, in the perimeter of the North Pesteana quarry, there were identified erosion and sufosis zones, fissures and cracks, superficial landslides that did not affect the overall stability, these modifications being corrected as the work front advanced, but also a larger sliding in early 2018 on the eastern slope of the quarry that affected the structure of the road that serves the mining perimeter.

So far, the deformations and changes occurring on the steps of the quarry and the inner dump of North Pesteana mining perimeter did not affect the overall stability of the quarry or the inner dump, except for the landslide from the eastern slope of the quarry, but they may endanger the stability of the individual steps.

Generally, signs of erosion are the gullies, ditches of small dimensions. Also, the sufosis areas were of small and medium sizes, and did not affect the mining works or the stability of the career steps, but they could seriously jeopardize the safety of employees as a result of rock falls. Fortunately, during the observation period, no such event were recorded. Given the short service life time of the quarry steps, these types of changes are remedied as the exploitation works advance. Given the fact that with the advancement of the work fronts new deformations and changes occur, it is recommended to continuously perform visual and geotechnical analyzes, where appropriate, and to intervene as quickly as possible to prevent these phenomena from occurring on a larger scale.

Considering the behavior of the rocks from the quarry and inner dump steps within the North Pesteana mining perimeter under the influence of the external or internal factors, it is recommended to pay close attention and adequate intervention for the case of definitive slopes of the quarry, that have a much longer service life time than working steps, for decades, to increase the stability reserve and the degree of safety of the objectives in the areas of influence.

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LANDSCAPE AND FUNCTIONAL RECONSTRUCTION OF THE PERIMETER AFFECTED BY TURCOAIA - IACOBDEAL QUARRY POST-CLOSING

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Abstract: Environmental legislation and the one ruling the mining industry require the ecological rehabilitation of areas affected by mining activities, which are currently under way, with the cessation of productive activities. From this point of view, one of the most active areas of exploitation, especially of construction and ornamental rocks, is located in Tulcea County (more precisely, there are 50 quarries occupying a total area of approximately 792 ha). We also have to bear in mind that the largest one, Turcoaia (130.58 ha), is located near areas with special protection regime (Danube Delta Biosphere Reservation and Măcin Mountains National Park). In this context, it goes without saying that beyond the limitation of negative environmental impacts for the period during which the exploitation activity will continue according to the license, it is imperative to have a project whereby, at the end of productive activity, the quarry will be ecologically rehabilitated and functionally reintegrated into the general context of the area. For these reasons, we propose, that starting from a brief presentation of the current activities and continuing with the short description of the environmental impact and the necessity of developing an ecological rehabilitation project, to finally set a concept in the general approach, for the ecological rehabilitation of Turcoaia quarry (without, entering into design details or evaluating the costs of its implementation).

Keywords: ecological rehabilitation, granite, mining, Turcoaia quarry

1. INTRODUCTION

Extractive industry, regardless of how it is performed, always leads to long term negative effects on the environment. The environmental component that suffers the most as a result of mining activities is land, and with it the entire ecosystem in the area. The most significant destructive effects of open pit mining are produced, both by the quarry and the associated waste deposits [3].

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The problem of ecological rehabilitation of the lands, degraded by mining, is settled by mining and environmental laws, witch impose their reintegration into the surrounding ecosystems or in the economic circuit after the mining activities are stopped. The decision process regarding the development of mining areas at the end of operations represents a challenge for all political actors involved in planning the use of land, landscape planning and environmental planning, representing at the same time a great responsibility.

The main intervention to eliminate the environmental impact of mining activities is represented by the ecological reconstruction of the affected areas at the end of exploitation, and consists in establishing all the necessary measures to prepare the area for an environmentally compatible reuse.

2. GENERAL DESCRIPTION OF THE AREA

The Turcoaia - Iacobdeal exploitation perimeter is administratively located in Turcoaia village, Tulcea County, on the right bank of the Danube, about 64 km from Tulcea (Figure 1).

Fig. 1. Location of Turcoaia quarry [9]

The major overall structure of the North - Dobrogea area is the result of hercinic orogenesis and eco - and neochimeric tectogenesis.

The massif, in which the Turcoaia quarry is located, is a granite body, in the center of which there are alkali microgranites and a granite with ribeckite and egirin, the latter having a gray color with rosary shades, with a hippidomorphic - granular structure, massive texture and irregular cracking. The granite is strongly cracked and altered, especially in the upper part of the massif [6]. The nearest watercourse is the Danube River with Măcin branch, about 2 km west of the quarry. From the hydrogeological point of view, the conditions from the area of the exploitation perimeter are favorable for the execution of the works, the area being arid, devoid of permanent underground bodies of water.

Măcin Mountains are characterized by a pronounced temperate - continental climate with submediterranean influences in areas with higher altitudes and with obvious aridity influences in the southern part of the protected area. The average annual temperatures are of 10-11°C and average rainfall does not exceed 400 mm, the Măcin Mountains being the most arid mountains in Romania, the predominant winds in from north and northeast and they contribute to the lytic erosion [6].

3. OPERATIONAL CONTEXT

The area of land, of 130.58 ha, approved by Concession License no. 163/1999, includes the following subdivisions: the Turcoaia perimeter of exploitation (itself); access roads in the quarrying perimeter and for transporting aggregates; processing plant - crushing; conveyor belt network, sorting - washing plant; finished material warehouses - loading platforms; vehicle and machinery platform; warehouses and administrative premises; fuel and explosives storage facility [6].

3.1. Extraction technology

The preliminary production capacity for the next 10 years of the Tucoaia quarry was set according to the orders of the interested economic agents, averaging 1,750,000 tons per year. The exploitation method to be applied is by transport to the external waste dumps, the extraction being carried out in descending steps, the blasting being carried out with the help of the explosives placed in the drill holes made with the Atlas-Copco drill.

The exploitation activity aims to extract the steps without interruptions, taking into account both the limits of the approved reserves in horizontal and vertical plane, as well as the limits of the exploitation perimeter. The material resulting from blasing operations is loaded with excavators with thermal engines (Caterpilar 365 Excavator; Caterpilar Excavator 385), in dumper trucks (Astra 25 t and CAT 775 50 t) and transported to the crushing plant for processing (Figure 2a) and in Gura Arman loading dock (figure 2b).

a b

Fig. 2. Crushing plant and loading dock

In the Turcoaia quarry, the granite extraction activity is carried out as follows: ***a. Opening the deposit*** - the deposit is opened from the top, the elevation + 305 m, to the bottom where the reserve volume was calculated, namely the +130 m elevation; ***b. Preparing the deposit*** - the deposit is fully open, no preparatory work are required, the surface layer (the tailings layer) of negligible thickness is extracted with the useful rocks, being separated by pre-sorting operations; ***c. The exploitation of the deposit*** - the exploitation activity takes place in the eastern part of the mining perimeter, namely the Manole Fountain area on the basis of the existing projects; ***d. Processing*** - the preparation activity consists of crushing the rough quarry stone, obtained by blasting with explosives and sorting - washing the crushed mining products; ***e. Depositing the waste material*** - tailings resulting from exploitation, as a result of technological losses, represents 3-4% of the total. It is temporarily stored in the area of the crushing plant, occupying approximately 800 m^2, and is latter used for the arrangement and maintenance of the quarry roads [6].

3.2. Brief description of the environmental impact

The impact on the environment is defined as a set of changes produced on the environment by a process, an activity or anthropic action. It is the synergistic effect of a disturbance over a given environment or environmental component [2].

The impact on the atmosphere - The main pollutants and their sources are represented by:
- *combustion of liquid fuels (diesel)*, through the operation of the equipment and the means of transport which consume approx. 740 t/year of diesel evacuating directly into the atmosphere exhaust gases (SO_x, NO_x, CO, CO_2, COV, CH_4) and dust;
- *explosives blasting* for rocks exploitation (4 times/month) by emitting harmful gases (CO, NO_x) and powders from detonation of explosives and rock dislocation;
- *the extraction and processing of granite*, by loading, transporting, crushing and sorting the useful rocks, resulting in dust emissions.

The impact on water - The main polluting agents of water and the pollution sources in Turcoaia quarry area are as follows:
- *drinking and industrial water supply;*
- *drainage/sewerage system of rainwater*;
- *wastewater discharge* - domestic sewage from personnel and laboratory and wastewater resulting from the technological process at the granite aggregate washing-sorting plant.

The impact on land and soil - the main problem is the occupation of significant land areas, as can be seen from table 1.

In order to be able to carry out the environmental impact and risk assessment by the RIAM method, the area actually occupied and affected by the quarry and mining facilities was reported on the total leased area.

Table 1. ***Surfaces of land occupied by Turcoaia quarry***

Specification	Surface [ha]
Granite mining perimeter	85.67
Manole Fountain perimeter (including temporary warehouses, loading bunker, administrative space)	6.86
The perimeter of the Turcoaia sorting - washing plant (including sorting facility, aggregated temporary storage, administrative site)	5.72
Iacobdeal perimeter (including explosive storage area)	21.25
Conveyor belts	0.14
The land area outside the mining perimeter (including historic tailings dumps)	9.00
Exploitation roads	0.62
Free land for construction and utilities	1.32
TOTAL	**130,58**

The impact of noise/vibrations - special problems in terms of noise pollution occur when the solid rock is dislocated by drilling and blasting works. When performing blasting works in quarries, the environment is affected in five ways, being subject to seismic waves, aerial shock waves, discarding pieces of broken rock from the massive, dust and gas [6]. The minimum value is of 58.7 db (A), the maximum value is of 63.3 db (A), resulting in an average of 61 db (A), (the average value does not exceed the maximum admitted limit by STAS, of 65 db.

The impact on biodiversity - considering that no protected species and habitats have been identified at the site and in adjacent areas, a number of environmental impact mitigation measures have been established to maintain the integrity of the ecological functions of the protected area (area of Community interest) [6]. The impacts of the exploitation activity on the biodiversity form the ROSPA0073 Măcin - Niculiţel (which includes the Turcoaia quarry on the south-western boundary) is minimal.

3.3. The Rapid Impact Assessment Matrix (RIAM)

In order to emphasize which of the environmental components will be most affected by an activity, the RIAM method can be applied. It is based on a standard definition of the important assessment criteria and the means by which quasi-quantitative values can be deduced for each of these criteria, represented by a concrete, independent score [5].

The simple structure of RIAM allows a rapid and accurate in-depth reconstruction and analysis of selected components. This flexibility makes the method a powerful tool both for performing and evaluating EIAs [5]. For Turcoaia quarry, the final assessment matrix of the impact, by RIAM method, is done in table 2.

Table 2. *Environmental impact assessment by RIAM method*

Environmental component	Evaluation criteria					Env. score, ES	Impact category, CI	
	A_1	A_2	B_1	B_2	B_3		Code	Description
Air	2	-1	3	2	2	**-14**	**B**	***Negative impact***
Water	1	-1	3	3	3	**-9**	**A**	***Small negative impact***
Soil	1	-1	2	2	2	**-6**	**A**	***Small negative impact***
Noise/vibrations	2	-1	2	3	2	**-14**	**A**	***Negative impact***

Applying the matrix method for rapid assessment of the impact of pollution (RIAM) it was concluded that the environment of the area related to the activities of the Turcoaia-Iacobdeal quarry is ***affected from slightly negative to negative***.

4. GENERAL CONCEPT FOR THE ECOLOGICAL REHABILITATION OF THE AREA

Considering that in the next 8-10 years the exploitation activity of the granite massif will cease, the problem of ecological rehabilitation of the affected perimeter is a question.

As pointed out in the first paragraph, the quarry is located in the vicinity of the Danube Delta Biosphere Reservation, the Măcin Natural Park, but also to short distance from Turcoaia village.

Based on these considerations, and taking into account the modeling system of the territory proposed by Turowski [7], we can conclude that it is appropriate to rehabilitate the area for recreational purposes.

This type of recovery involves systematic interventions generally made simultaneously with naturalistic recovery, coupled with the installation of specific structures based on destination [1].

The first step to be taken is to rehabilitate the existing road infrastructure, in this regard it is necessary to modernize the access road in the northern part of the quarry (in order to facilitate the access of vehicles both during the reconstruction of the land and after, for access for tourists). The second access road, connecting Turcoaia village with the quarry, will not be used for car access but for practicing certain types of sport (downhill, motocross etc.).

Characteristics

- Width of the roadway 6.00 m
- Width of the gutter 2x 0.40 m
- The transverse slope in the current section 2.5%

Structure of the roadway

- wear layer – asphaltic concrete BA 16 thickness 4 cm;
- binding layer – asphaltic concrete BAD 20 thickness 5.00 cm;
- base layer – chorused stone thickness 15.00 cm
- foundation layer – river ballast thickness 10.00 cm;

- shape layer – river ballast thickness 10.00 cm [4]

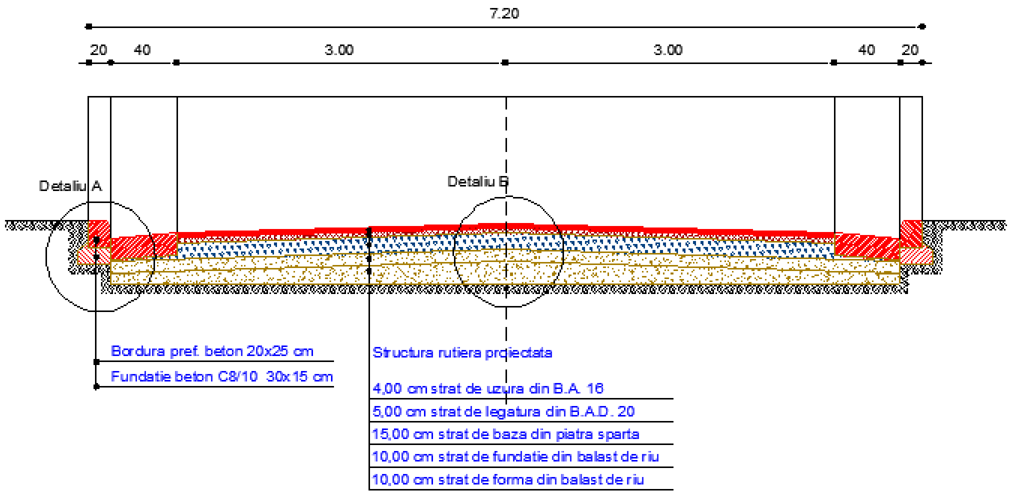

Fig. 3. The transverse profile designed for the auto / moto access road [4]

In parallel with the road infrastructure, the construction of utility networks (drinking water supply, sewerage and gas pipeline) is also required. The utility grid path will be the same as the northern access road.

In the next stage it is necessary to arrange the parking spaces, north of Lake Iacobdeal, as well as the holiday village (with modular houses such as shown in figure 4) and camping areas will be arranged.

All modular houses will be connected to utility networks.

In the proximity of tourist accommodation areas (modular houses and camping areas) it is necessary to arrange concrete and fenced platforms for the selective collection of domestic waste.

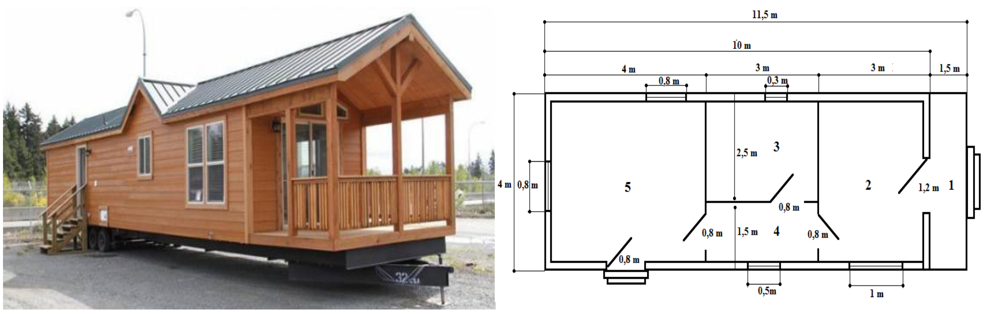

Fig. 4. Modular houses [8]

As can be seen from Figure 4 such a modular house is divided into five areas with different utilities: 1. Porch, 2. Kitchen 3. Bathroom, 4. Aisle, 5. Room.

On the 9 existing waste dumps there will be installed solar panels (those with favorable exhibitions to the Sun) and wind turbines that will be able to ensure the energy independence of the whole newly created recreation area.

Next, from the area where the loading dock is currently located and up to the top of the massif (elevation +305), a cable transport system (cable car) will be built to facilitate access for those who practice different sports but also for a panoramic view of the region.

In the area of former granite transport facilities (Figure 5), a tyrolean route will be arranged.

Fig. 5. Former transport installations

Lake Iacobdeal (Figure 6) will be arranged for swimming, meaning that a diving trip will be built, but also for boat trips, being necessary to purchase them.

Fig. 6. Lake Iacobdeal

The Iacobdeal 2 quarry lake will be located on the second operating stage (upper berma) in the southern part of the exploitation perimeter (Figure 7).

The lake will have a maximum depth of 4 m (on the north-eastern side, towards the base of the third stage) and the minimum one meter (on the south-western side, towards the edge of the step).

Fig. 7. Location of Iacobdeal 2 lake

The destination of the lake will be mixed, swimming or boating.

The cableway installation (telegondola) - this facility will link the Măcin branch to the top of the quarry (+300). The embarkation station will be built in the Turcoaia area (the current site of the scrubbing/sorting facility) and the upper berth arrival/departure station of the last step to be exploitation (after proper profiling). It will also be a belvedere point of. The total length of the installation will be of 2 km.

The installation will be fitted with 10 metal pillars, the cabins will have 4 seats and will have a transport capacity of 500 pers/h.

The final steps of the quarry, with heights between 20 and 30 m, will be arranged for climbing. These climbing routes can be used by both tourists (of course under the supervision and guidance of qualified persons) and by professional climbers in some competitions that may be organized (generating incomes for the local community).

5. CONCLUSIONS

The experience and successful transformation of closed mining objectives into theme parks and recreational areas from countries in Western Europe and America is able to provide examples and know-how that can be successfully implemented in Romania.

Turcoaia quarry offers an opportunity to rehabilitate the area, to reuse some of the existing installations and the waste dumps after western models and also the opportunity to develop a unique project in our country. Surely such a project requires a more detailed study and a feasibility one, but, as was shown in the paper such a complex with multiple functions is suitable to be realized in Turcoaia area. A complex with sportive and recreational role can be regarded as a first step towards reviving the area, especially if we consider the shock that the cessation of productive activity will have on the local community.

Finally we must take into account that the realization and functioning of such a complex (in an area with a high touristic potential given by the vicinity of Danube Delta Biosphere Reservation and Măcin Natural Park) will generate jobs and income for those directly involved but also for the entire community of Turcoaia village, leading to a sustainable development of the region.

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CRITICAL ANALYSIS OF THE GEOMORPHOLOGICAL CHANGES AS A RESULT OF MINING ACTIVITIES IN BERBEŞTI BASIN

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Abstract: The geomorphological changes in the Berbeşti Mining Basin have an impact on the environment by: excavating the mining mass and depositing the tailings in the waste dumps, the contrast between the black color of the coal with the general green landscape, the local damage to vegetation and fauna, the change of groundwater regime and aquifers, the exposure of the area to uncontrolled uses of land, affecting local communities. The impact of geomorphological changes in the Berbeşti Mining Basin on the land and the relief is manifested by the radical modification of the morphology of the land, the hydrological and hydrogeological regime, the vegetation, the fauna and the soil. In this paper beside the detailed description of the impacts mentioned before, for it's identification we have applied the impact networks method.

Keywords: geomorphological changes, impact identification, mining basin, environment

1. INTRODUCTION

The geomorphological changes in the Berbeşti Mining Basin (M.B.) have a major negative impact on the environment, starting from the occupation and degradation of some impressive land surfaces as a result of the activities of this industry [1].

The impact of the geomorphological changes in Berbeşti on the land and the relief is manifested by the radical modification of the morphology and initial geomorphology of the land, the hydrological and hydrogeological regime, the vegetation, the fauna and the soil. At the same time, other effects related to the above-

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mentioned modifications, such as: air pollution through the dispersion of sedimentary particles, the transport of equipment and extracted materials, resulting in emissions of different pollutants (carbon oxides, sulfur oxides, nitrogen oxides, powders, etc.), pollution due to increased erosion. They cause air pollution and worsen the quality of life, increasing the risk of illness. Ground or surface water pollution through oil spills, acidified water formation, effluent and unpurified waste disposal, nutrient degradation (eutrophication risk) [9]. Between water and other environmental components there are interdependent relationships provided by the hydrological cycle through which the degradation of water quality is directly or indirectly reflected on man. Worsening soil quality recovered by loss of balance between water-air-nutrients as a result of the excavation, transport and storage process, soil erosion.

The characterization of environmental components for the purpose of identifying the impact induced by the geomorphological changes from Berbeşti Mining Basin on the environment should highlight the relations between them, the synthetic frames, based on the various interpretative keys of the environmental system, all of which to achieve a certain level of detail.

2. DESCRIPTION OF THE MOST IMPORTANT IMPACTS

Geomorphological changes irrespective of how they take place always lead to long-term negative effects on the environment. The environmental component that suffers most as a result of these changes is the soil/land/physical support and with it the whole ecosystem in the area [7].

2.1. The impact on soil

The impact of geomorphological changes on the soil manifests it's self at local and regional level, on long-term and refers to:
- modification of the local morphology and the appearance of the mining anthropic relief, marked by positive relief forms such as waste dumps and negative relief forms such as open pits (Ruget, Olteţ, Panga, Berbeşti);
- disturbance of the physico-chemical equilibrium of the geological environment, produced by geological, hydrogeological and geotechnical prospecting through drillings with significant, inevitable and irreversible effects on groundwater and groundwater systems, on small surfaces and volumes and limited in time;
- occupation of soil through the construction of buildings, roads, infrastructure and mining transport;
- the soil layer is recovered from agricultural land, but can not be recovered from deforested forest lands, and as a result it is destroyed and lost;
- roads are dislodged, excavated, transported and stored on sites down to tens and even hundreds of meters deep;
- the resulting materials, sterile and useful mining masses acquire geotechnical features other than basic rock;
- deposited waste create new compaction and affects the overall stability on new sites;

- destruction of the natural geological environment (Fig. 1);

Fig. 1. Modification of natural geology in Panga open pit

- physical-chemical imbalance of the basement produced by excavations and dumps that extends also in the nearby areas;
- soil degradation and decrease of their fertility class on large areas, by changing the initial destination of agricultural or forest land and organizing activities related to exploitation [5].

The potential environmental impact on the soil is related to the risk of accidents or catastrophes that relate to:

- the risk of environmental accidents caused by the self-ignition of coal in bed or surface deposits;
- accidents or catastrophes leading to major disruptions of the geological environment, mixtures of aquifers, penetration of surface pollutants;
- the adoption of organizational measures and exploitation technologies, which do not limit the actual "in situ" action to the strict necessity and are not adapted to the specific geological structure, can amplify and diversify the complexity of the effects on the ground and subsoil;
- local instability of geological strata, favoring landslides and rock falls [5].

The positive impact on the land in the excavation/dumping areas is generated by the actions of ecological recovery (Fig. 2).

Fig. 2. Integration into a natural environment of surfaces from the Ruget external dump

The land from the surfaces gradually released from the technological tasks can be rendered in the agricultural or forestry circuit (the external dumps, the inner dump, and the areas with industrial or administrative activities, the steps of the open pit). These activities should be carried out before and after the closure of the mining perimeter, ensuring that the desired results are obtained [7].

2.2. The impact on morphology and landscape

The impact of geomorphological changes on morphology and landscape is a long-lasting one. It refers to the modification of the morphological configuration, being the most frequent reason for degradation of the landscape. Over time, morphological alteration reaches a maximum value, being dependent on the exploitation and construction phase of the waste dumps. Morphological alteration is closely related to the location of the open pit and the initial morphology of the surrounding areas [2].

In the case of the open pits developed in Berbeşti hilly area, the morphological alteration (Fig. 3) is quite impressive, being obviously dependent on the dimensions of the pit and its working fronts, but especially the relationship between these dimensions and those of the natural slope on which is located [3].

Fig. 3. Modification of the morphological configuration – Panga open pit

The total of the altered products is subordinated to the techniques and technologies adopted for the exploitation of the lignite: the berms and the steps determine, by their geometrical alternation, a configuration that did not exist previously, being non-natural; a non-uniform slope determines, on the contrary, a lower level of morphological alteration. In open pits located meadow areas, present in Berbeşti, morphological changes can be offset much easier, by partially or totally filling the remaining gaps with different materials [10].

The emergence of waste dumps in Berbeşti M.B., whose heights can reach 90-100 m, change the original relief and leads to the perturbation of the overall perception, forcing the eye to a continuous adaptation, producing a sense of perceptive chaos. For example, at the confluence of Olteţ River with the Târâia brook, in the meadow area, an external waste dump with the designed height of 90 m (currently has a height of 65

m) is to be constructed. Any modification of an element or environmental component determines the change of the local ecosystem, the microclimate, the appearance of other topoclimates with effects on the community [2].

Waste rocks discharges have a negative visual impact, determine land occupancy and diversion from original uses, increase or enhance stress levels in the local community, going up to the risk of illness, and involving high costs of land rehabilitation in the area [7].

Land degradation involves the phenomenon of desertification of the territory, which does not occur immediately, through a strong and recoverable destruction, but only after a long time. The process of degradation of fertile soil lasts throughout the exploitation until the improvement works are carried out and has always negative influences, but it varies according to the unit characteristics of the landscape [5].

The Berbeşti area prior to operation was a forested area, the partial destruction process by excavation produced major degradation, especially with regard to the time required to rebuild a similar entity. In the agricultural area of Berbeşti M.B., desertification interrupts the continuity of typical crops, (Fig. 4), but the recovery of these lands is much faster [3].

Fig. 4. Reduction of agricultural activity by construction of waste dumps **-** Panga mining perimeter

Lignite deposits occupy the land in the area, dust drift through the wind, it is deposited on vegetation, or is inhaled by the inhabitants. It prevents the process of photosynthesis, reduces the captured amount of CO_2 by plants, increases the concentration of CO_2 in the air, reduces the quantity of O_2 eliminated in the air, participate in the enhancement of the greenhouse effect [5].

The land becomes similar to a lunar landscape, the dust carried by the winds is inhaled by humans and animals, affecting the respiratory system, and the remaining gaps determine the risk of accidents by falling rock, collapses, erosions.

The small depressions involve the accumulation of rain or underground waters, the formation of ponds, marshy areas or the formation of open pit lakes (Fig. 5), the increase of the quantity of evaporated water, the emergence of new ecosystems, the modification of microclimate.

Fig. 5. Panga pit lake

-modification of the relief due to excavation and dumping activities (destructive activities), thus creating anthropic relief inversion [1].

2.3. The impact on air

The impact on the air generated by the geomorphological changes is local, temporary and refers to:

- particulate matter suspensions - sedimentary powders during excavation, conveyance on the belt (Fig. 6), waste dumping, affected by geomorphological processes, with strictly local effects, around the points of activity and limited in time to actual periods of activity [5].
- combustion gases and sedimentary dusts in the air, due to the operation of the mining perimeter of own or leased internal combustion machinery and means of transport;
- volatile hydrocarbons, by natural respiration at the fuel store, or evaporations when handling fuels;
- acoustic emissions of different origins, fixed or mobile, produced by technological equipment or means of transport, with local effects limited to distances of several hundred meters of sources and limited in time to their operation [11].

Fig. 6. The belt conveyance, coal handling has an impact on the air through particulate emissions in suspension

The quality of the air is mainly affected by suspended particulates and sedimentary dusts discharged locally under the influence of geomorphological changes (Fig. 7). According to Fig. 7, sedimentable powders from Berbeşti in 2017 had a concentration below the 0.150 mg/cm/24h allowed by legal regulation.

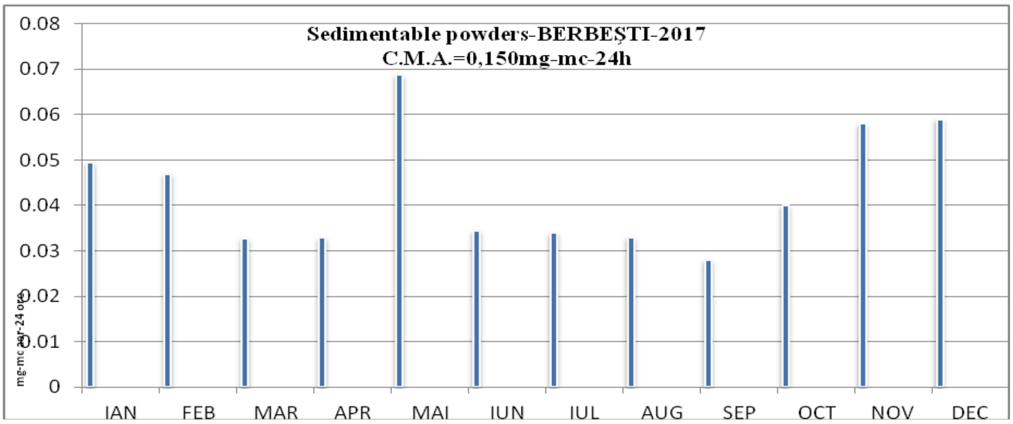

Fig. 7. Graphical representation of sedimentary powders in the town of Berbeşti (2017)

The potential environmental impact is maintained throughout the lignite exploitation period, manifested by a possible zonal pollution with sedimentary dust (especially coal dust) in extreme weather conditions, such as droughts and strong winds. Large particles of solid coal from the pit, waste dump, coal deposit, open land, affecting neighboring local communities, causing discomfort to the population. The dispersion patterns are altered by the anthropic change of local morphology: waste dumps, lignite deposits or remaining gaps [8].

2.4. The impact on vegetation and fauna (ecosystems)

The impact of geomorphological changes on vegetation and fauna is a local and temporary but long-lasting impact, and it concerns:

- destruction of natural flora and fauna as a result of soil removal activities;

- reducing the forestry fund by deforestation in the quarrying and dumping sectors and the complete disappearance of forest ecosystems on these areas;
- reduction of the exploitable wood mass in the forest fund, even after the ecological reconstruction of the areas;
- diminishing the balance of the ecosystems predominant in the area, the productivity of the ecological systems or even the disappearance of some associations;
- resettlement of vegetation is rapids (Fig. 8), a few years, but with modified structure [3].
- restoration of natural vegetation with associations of species characteristic of the area over long periods of time (Fig. 8).

Fig. 8. Reinstalled vegetation on North Panga exterior dump

According to the Environmental Impact Study, conducted in February 2017, the extinction of some species has been highlighted while at the same time endangering others. Thus, with regard to the number of vegetal species, a study by ICSITPML SA Craiova shows the following situation:

- prior to the start of exploitation of the lignite in the hilly and carboniferous area of the region there were 806 species of cormorants, out of which 45 represented rare or endangered species [11];
- the analysis of the current flora has revealed a number of only 389 species of cormorants, of which only 16 are endemic species. It is noteworthy that some species have acquired this status by the disappearance of the specific biotope, a situation determined by the mining exploitation [11].

Regarding Panga open pit, no inventory of plant and animal species has been carried out, but obviously exploitation has determined and will lead to the removal and even the disappearance of most animal and plant species.

The impact on fauna is highlighted by:

- lack of wealth of species and individuals, of invertebrate fauna;
- ecosystem imbalances through the disappearance of key faunistic groups, species, numerical reduction of individuals due to stress factors;
- migration of terrestrial reptiles and amphibians in areas neighboring the exploitation;

- modification of the area of ypical birds, especially hatching, that migrated from the exploitation area;
- reducing the population of mammals to zero in the area by removing them to areas near the mining field, with the same characteristics of the ecological niche [7].

The quality of ecosystems is primarily affected by a severe imbalance caused by total disappearance, migration or decrease of the number of individuals of the vast majority of species in the mining perimeter in exploitation.

The potential environmental impact persists throughout the exploitation of the reservoir, resulting in a permanent increase in the vulnerability of the vegetal and animal species in the area [6].

2.5. The impact on the human community

The impact of geomorphological changes activities on human collectivities has a complex aspect with negative and positive effects, local and zonal, short and long lasting and refers to:
- modification of the land use and land ownership regime, through Berbeşti area;
- partial decommissioning of the villages by the open pits, dumps or industrial sites (private households, social constructions, churches – Fig. 9, cemeteries);

Fig. 9. The church of St. Nicholas, built in 1776 – displaced

- the resettlement of the inhabitants, with psychological effects on the people, uprooting, although the new village and new dwellings have utilities networks with high comfort;
- affecting water sources of localities (groundwater or springs) that generally have individual wells;
- temporary and local damage to the local community with coal dust and dust, in weather conditions favoring their spreading;

- noises and vibrations due to heavy car and conveyor transport;
- industrial landscapes specific to excavation and waste dumping over long periods of time, for decades, instead of natural landscapes (hills, forests, pastures, valleys, etc.);
- instability of some areas, favoring landslides, affecting local roads and private households, causing their relocation [13];
- promoting the emergence of professional and non-professional diseases among the population;
- a positive effect is represented by the social economic development of the area, the construction of housing districts, educational units, town hall, cultural home, health care units, commercial spaces, services and small local industry, technical-community networks, paved county network roads, local roads, communal roads and railways, job creation for the local population.

The potential environmental impact is maintained throughout the exploitation period of the reservoir and is related to the risk of accidents or environmental disasters that could affect localities (landslides, fires, etc.). There is currently and remains a population sensitive both to the global effects of coal exploitation on the environment and living conditions, as well as on the area's prospects of cessation of mining activities.

3. ASSESSMENT OF THE IMPACT GENERATED BY THE GEOMORPHOLOGICAL CHANGES IN THE BERBEŞTI MINING BASIN ON THE ENVIRONMENT

The Environmental Impact Assessment procedure is a decision support system designed to provide the competent authorities with certain decision-making elements, establishing scientifically the possible environmental effects of the actions to be implemented. The implementation of the environmental impact assessment is a correctable and transparent process based on clear working methods and data, informational sources and guaranteed management systems. Being a flexible and open process, it allows for changes in every stage of its realization [7, 8].

Berbeşti M.B., with open pit lignite exploitations is an artificial space that functions on the basis of new rules imposed by anthropic - natural interaction. The main features of the impact of geomorphological changes are:

- spectacular relief inversions, depression morphology is replaced by varied anthropic horn shapes; while the prominent areas are flattened or even leave the place of subtopographic or underground cavities of anthropogenic origin;
- shaping the slope profile by adding or removing slope elements;
- "anthropic parasitical chenges" of the original morphology through mining technical structures (waste dumps, open pits etc.);
- the superiority of anthropic modeling both in intensity and in terms of speed of manifestation;

- the establishment of conflicting relations between the natural components of the geomorphological system and the anthropic activity (pollution, landscape changes, lithological changes, pedo-vegetal and hydroatmosferic degradations etc.).

The network was structured taking into account the main geomorphological changes, namely: modifications of the microrelief by the appearance of mounds, creeks, modifications of the macrorelief, the disappearance of hills, slopes and the appearance of positive reliefs marked by large waste dumps (Olteț, Ruget, Panga, etc.), due to the disappearance of the negative relief forms (hydrographic valleys), the accumulation of waste due to the local exploitation, by fertile soil deposits, lignite deposits, ramaining voids, small depressions [2].

The most important effects are induced by land occupation of large areas (through waste dumps, lignite deposits, accumulations of residues), deforestation, extraction of the fertile soil, installation and putting into operation of technological lines and causing numerous morphological and geomorphological changes, changes in the geotechnical characteristics of rocks as a result of their excavation and transport, watering of aquifers and regularization of water courses, works involving the modification of the hydrological and hydrogeological regime by quantitative and/or qualitative degradation of surface and underground waters [1].

The geomorphological processes and phenomena generate effects on the surfaces of the waste dumps and their neighboring areas due to the change of the local equilibrium: superficial landslides (on the steps and slopes of the dump), drainage (given the sandy substrate), pseudosoilifluxions (in the flat areas and at the top level of the dump), the compaction (on the smoothened surfaces), the muddy flows (on narrow surfaces, during high precipitations and on the background of some preliminary landslides), wind erosion especially during the construction phase (causing the dusting of the area of Târaia's corridor) [1].

Geomorphological changes have an impact on local hydrology: the groundwater has undergone changes (both in terms of qualitative and quantitative components), the hydrogeological dynamics undergo local changes, the surface leakage and the meteorological water filtration ratio has changed substantially (the consequences seen in the increase of the solid flow of the albedoes, the increase of the anastomosis tendencies, the over-dimensioning of the dewatering cones and the premature clogging of the lacustrine troughs etc.), flooding of the dumps (due to the poor drainage) [2].

The climatic changes related to the geomorphological ones are felt by modifications of the dispersion of dusts, inhaling the dust by locals, animals, increasing the risk of disease, depositing on vegetation, reducing photosynthesis, forming a local microclimate.

Ecosystems are modified due to geomorphological changes by radically changing the relief, (micro and macro). Practicaly all physical support is changed, the mutations of plant and animal species are dependent on the relief shape, the restoration of the ecosystems after the closure of the open pits needs a long-lasting period for the emergence of other ecosystems [7].

To assess the impact of geomorphological changes in the Berbeşti Basin, we used the impact network of geomorphological changes on the environment (Fig. 10).

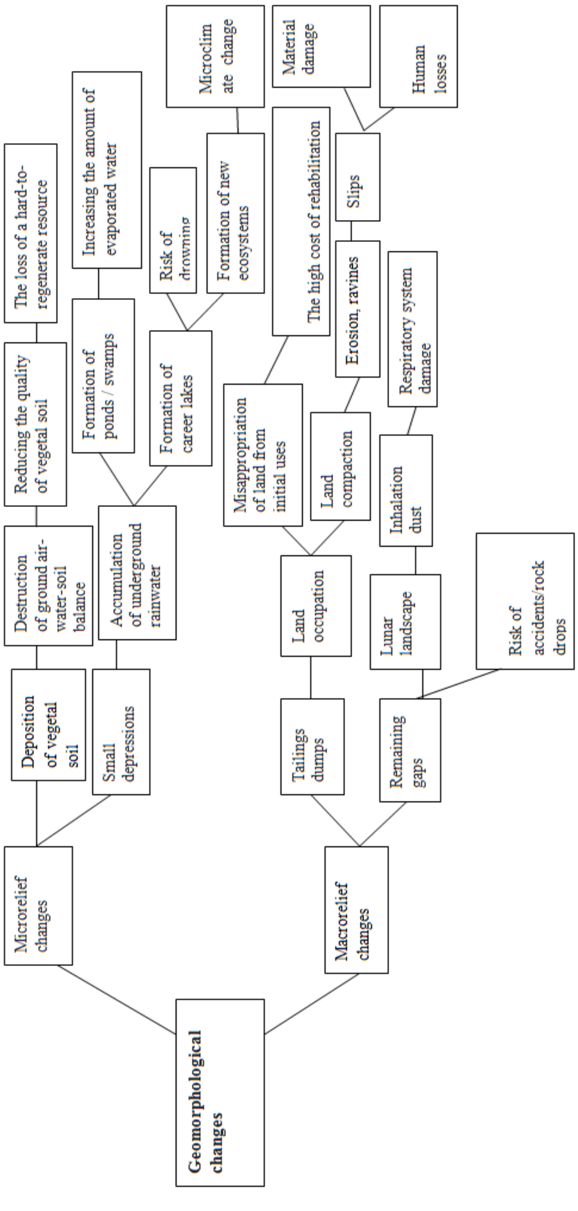

Fig. 10. The impact of the geomorphological changes on the environment in Berbeşti Mining Basin

Any change in environmental components ultimately involves the emergence of new ecosystems, the change of microclimate, the enhancement of the greenhouse effect, the impact on the local community, consisting of displacements, conflicts over land use, the destruction of recreational areas [6].

Between the environmental components there are complex, interdependent relationships that favor the transport and transfer of pollutants from one environmental component to another. Through these, over time, open pit exploitation favors the degradation of land quality, the degradation of other environmental components, which directly or indirectly affects humans [7, 8].

Land degradation may take different forms and a correct diagnosis of the main forms of degradation for land is a necessary condition for proper rehabilitation. Reinstalling vegetation and fauna on degraded lands requires long periods of time and impressive material and financial efforts. Until this step is achieved, it is necessary to plan the recovery and rehabilitation of the land, a process involving the completion of several stages [6].

The functional reintegration of the supratopographic mining structures, such as waste dumps (post-exploitation management), involves their transformation from degraded and economically inefficient degraded areas into pleasant and economically useful areas.

The implementation and of land reclamation works with the cessation of operation or progressively, with the onset of works, is an essential stage for the 21st century mining, a stage that involves minimizing negative impacts on the environment generated by the exploitation of mineral resources [7].

4. CONCLUSION

The environmental impact of geomorphological changes is significant, inevitable and irreversible, with effects on aquifers, water and air quality, natural mineral resources, soil and subsoil, climate, geomorphology and landscape, land use, related industrial activities, human collectivities and housing. Running on a large surface and having duration of tens of years, the impact is even stronger as the affected environmental factors do not have the possibility to return to their initial state. The effects are local or regional, both short and long term, cumulative, being generated over the entire exploitation period. Even after the cessation of activity, it will be necessary to pass an important period of time for the area to establish a certain complex ecological equilibrium.

The land areas are generally affected by: the modification of the topography due to excavation at deep depths as well as the deposition of significant amounts of tailings in the waste dumps, the two elements representing cases of anthropic relief inversion, dust emissions and dust discharges into the atmosphere and on soil, mainly generated by mining and tailings transport, storage and handling changes the surface water quality - suspensions, metals, organic substances - through the discharges of quarry and household waters; combustion gases and particulate matter emissions from solid fuel thermal power plants and local car transport; soil damage due to the location of coal and waste deposits, the realization of all industrial constructions, as well as the uncontrolled storage of waste, materials or equipment.

The local geological structure, including the underground aquifers, alters the initial physical and dynamic physical and dynamic conditions due to excavations at depths of hundreds of meters as well as the replacement, after the cessation of exploitation, of native rock masses with excavated tailings dumps, where the configuration and geological structure of the deposits are different.

Another activity with major anthropogenic impact is the de-forestation and destruction of the vegetation carpet that have resulted in the destruction of species or the migration of others to areas that provide the living conditions and the climate specific to those species.

Identifying, estimating and assessing the impact of geomorphological changes on the environment in the Berbeşti Mining Basin by detailing changes in the environmental components (especially negative) shws the necessity of an ecological reconstruction project with a focus on Panga open pit.

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CONCEPTUAL MODEL FOR ECOLOGICAL LAND RECONSTRUCTION — CASE STUDY OF ROVINARI MINING AREA

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Abstract: The main intervention to eliminate the environmental impact of mining activities is represented by the ecological reconstruction of the affected areas at the end of exploitation, and consists in establishing all the necessary measures to prepare the area for an environmentally compatible reuse. The problem of ecological rehabilitation of the lands, degraded by mining, is settled by mining and environmental laws, witch impose their reintegration into the surrounding ecosystems or in the economic circuit after the mining activities are stopped. In the present paper we have considered the largest lignite open pits in Romania, which are located in Oltenia, south of the middle Carpathians Mountains. In this region coal mining activities occupied and degraded large areas of land, amounting almost 19,000 ha. The major negative impact from brown coal mining in Oltenia is bound to the pressures exerted on the land, vegetation, fauna and landscape. The paper also exposes the arguments backing up the necessity of a global approach of the concept of ecological rehabilitation and suggests practical solutions for the Romanian coal mining areas.

Keywords: brown coal, ecological reconstruction, mining, open pit, reuse of land

1. INTRODUCTION

In Romania, brown coal produces 20-35% (depending on the season) of the electrical power and about 20% of the thermal energy of the country. In the region of

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Oltenia, brown coal is extracted in 12 open pits, grouped in five mining basins (figure 1).

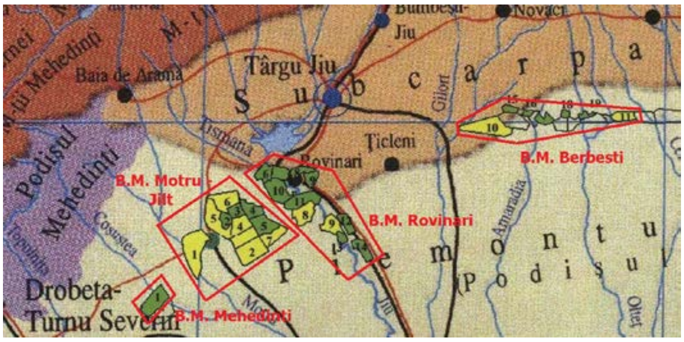

Fig. 1. Oltenia brown coal mining region

Extraction of brown coal in Oltenia began in the 60's of the past century, and since then closed to 900 millions tones of brown coal and over 5,000 millions m^3 of sterile have been extracted. On medium term, the contribution of brown coal in the energetic balance of Romania will be constant (according to the present strategy) [9], which mean that the production from the Oltenia open pits will have about the same level as during 2015–2017.

The 12 open pits use exclusively the continuous technological fluxes, consisting of bucketwheel excavators combined with high capacity conveyor belts and dumping machines (figure 2).

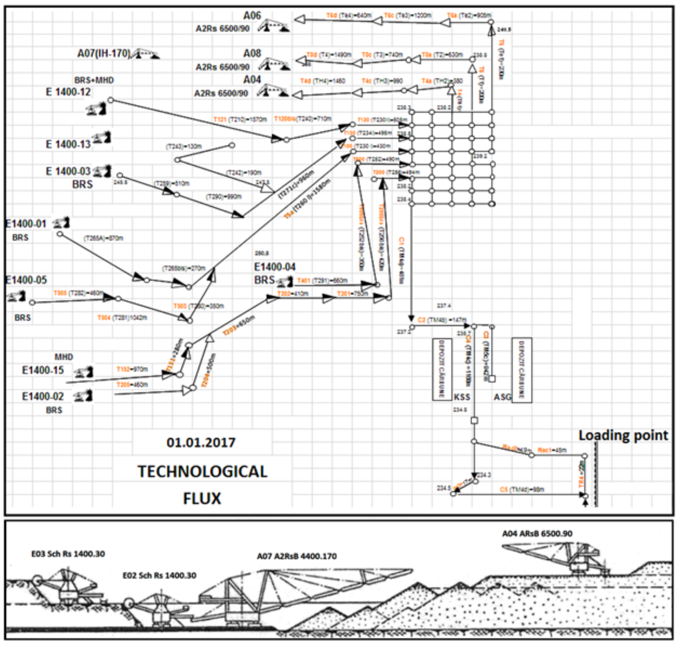

Fig. 2. Example of a technological flux

The extraction of brown coal in open pits includes the following operations: selective excavation, transport, deposition of waste rocks in dumps and deposition of brown coal in storage facilities. Excavation is performed by bucketwheel excavators, types: SRs1300, SRs1400, SRs2000, in steps with heights of 25-30 m.

2. THE IMPACT ON LAND GENERATED BY THE EXTRACTION OF BROWN COAL

Estimations are that the areas affected by the mining industry will be about 1% of the national agricultural surface. There is a special situation in the mining basins of Rovinari, Motru and Jilţ from Gorj country, where the affected surface exceeds 16,500 ha, representing 18% of the agricultural surface of the county.

Although, there are no real statistics about the surfaces affected by mining in the world and in Romania, we can say that the surfaces driven out of the economic use are increasingly greater, due to the extension of the open pit exploitation, and yet small if compared with the surfaces needed for industrial installations or transportation systems. As extraction begins, hills and plains are disappearing and the newly constructed waste dumps represent, for the beginning, a total change of the landscape. Another bad influence on the land is that great surfaces are occupied by waste dumps, transport and sorting installations, coal deposits etc. for a short or a long period of time. The main bad influences of the waste dumps on the environment are:

- bad visual impact;
- destroying and occupying large surfaces of natural or agricultural land;
- pollution of the surface and underground waters with chemicals or small particles transported from the waste dumps by rain or infiltrations;
- air pollution with dust and gases resulting from the oxidation (self infliction) of coal fragments present in the waste dumps;
- risk for human life and for the environment, or the destruction of infrastructure due to landslides (lack of stability) especially in the case of exterior waste dumps, etc.

The waste dumps also changed the landscape, as artificial hills with heights ranging from 15–20 m up to 90–100 m appeared in flat areas.

As a result of open pit mining, large surfaces of land, partly or completely affected, were driven out of the agricultural, forestry or natural circuit.

According to the Romanian laws, the mining operators must rehabilitate ecologically the areas affected by their activity and thus, in time, a part of them were recultivated. In the Oltenia area, form the almost 17,000 ha of land degraded by open pit mining, more then 3,000 ha have already been reintroduced in the agricultural or forestry circuit, and the rest are to be rehabilitated and reintroduced in the economy as soon as possible (progressively as the extraction process advances and the designed geometry of the waste dumps is achieved and immediately after the end of operations). Out of the affected areas, 80% were agricultural lands (from which, 25% were pastures and feedlots, which gave low and instable productions, 5% were orchards and vineyards with great variety but low productivity, the rest being cultivated with vegetables and cereals) and 20% were covered with forests.

At present, in Oltenia mining basin, for each million tones of brown coal extracted an area of 31 ha of land is degraded (destroyed).

There are surfaces affected by the open pit mining of brown coal in other areas of Oltenia (in Berbeşti mining basin situated in Vâlcea county and Mehedinţi mining basin situated in the county bearing the same name), but they represent maximum 17% of the affected areas located in Gorj county (in Rovinari, Motru and Jilt mining basins).

3. EXPERIENCE REGARDING LAND RECULTIVATION

Recultivation has been done on stages, as surfaces were freed by technological tasks, without following any preexisting plans or projects for rehabilitation.

Due to the climate, average temperature of 10.3°C, average precipitations of 753 mm per year, winds, influenced by the nearby mountains and hills and taking into account the deforestations, changes of the river flows, formation of artificial lakes and temporary or permanent puddles which produced changes in the micro-climate, more plantations have been experienced, as follows:

- orchards (66 ha) using: apple tree, plum tree, cherry tree, sour cherry tree, nut tree, mirabelle tree, hazelnut tree, etc. The apple tree and the plum tree gave good results;
- vineyards (40 ha) using: Royal Fetească, Muscat Otonel, Italian Riesling, Merlot and Cabernet Sauvignon. Best results were obtained for Royal Fetească;
- forests (over 1,000 ha) using: acacia, oak, poplar, pine, wild cherry tree, nut tree and chestnut tree. Best results were obtained by acacia tree, poplar, oak and esculent chestnut tree with double use, for fruits and for wood;
- cereals and technical plants (over 1,000 ha): rye, wheat, sun flower, corn, potatoes and peas;
- feedlots and pastures (over 700 ha). Best results were obtained by alfalfa and clover.

In the last years a few experimental lots (of no more then 10 ha) were cultivated with species of energetic willow and paulownia trees, the results being under analyses.

4. GLOBAL APPROACH OF ECOLOGICAL RECONSTRUCTION

For all the cases of re-modeling of the affected areas we must start from the economic activity that generated the degradation and take into account the future use. There is a fundamental relation between the shape and the morphology of the land and the type of re-use that should be regarded as crucial for choosing the new utilization. The re-modeling process must be done in order to offer multiple options, if a specific use is not foreseen [5], [7]. Best is to take a specific utilization into account from the very beginning and to adopt the best techniques according with the influence factors (figure 3).

Fig. 3. Factors influencing the recovering techniques of the degraded land

The decisions about developing a mining area at the end of the productive activities is a challenge for all those with responsibilities regarding land use planning, landscape planning or ecological planning. Such a decision must take into account a lot of elements, regarding the ecological characteristics of the area on one side and on the other side the social and cultural structure and needs of the population. Some of the reasons underlying the necessity for land re-modelling and ecological reconstruction in the areas affected by human activities (in this case mining) are:

- to eliminate the risk of landslides occurring in artificial land forms resulted from the industry (waste dumps, ash dumps, industrial or domestic dumps);
- to eliminate the negative visual impact of the areas having a moonscape aspect (specific to open pits);
- the need for reintegration of the affected surfaces in the economical and/or ecological circuit of the surrounding areas, leading to their total regeneration;
- improving the environmental quality;
- reducing the slopes (especially the final slopes of the pit) and thus reducing the erosion and stimulating the apparition of the vegetation.

The main objectives of such works are:

- to identify the possibilities to reuse the materials and installations;
- leveling the land with or without materials from other locations;
- filling the remaining holes with waste rocks (from other open pits) or water;
- decontamination of the lands (if necessary);
- reuse of the remaining holes for deposition of domestic or industrial waste materials from other regions.

The global approach of the ecological rehabilitation for an extended area is necessary because, according to the principle of “globality and intercausality”, the territory is a big and complex living organism, with multiple cultural and natural components that interacted in time and has an autonomously, self-sustainable life [8].

Any landscape is unique and irreproducible, the result of superposing in time of components of different origin (natural and cultural) producing always original situations. For such regions, planning and use of the land must take into account a unique design, capable to take into account the inside of the landscape with all its components. One of the causes of wrong planning of the landscape is taking the landscape on pieces or leaving out parts of it [6].

5. SOLUTIONS FOR ECOLOGICAL RECONSTRUCTION OF ROVINARI MINING BASIN

For this example, Rovinari mining basin has been chosen because it is the most affected by the open pit mining, as in this area are located 5 of the 12 active open pits from Oltenia (figure 4).

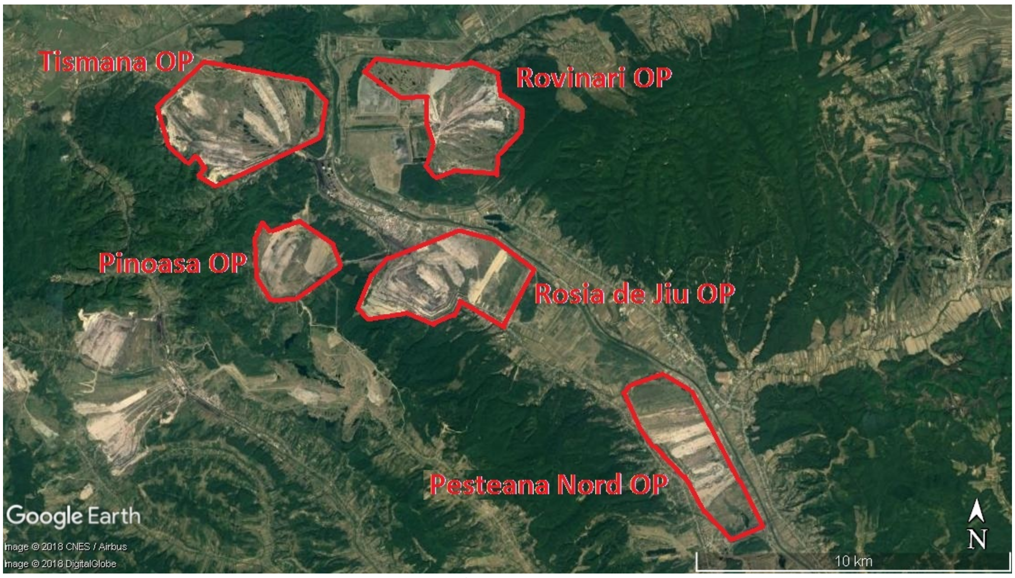

Fig. 4. Satelite photo of Rovinari mining basin in 2017

Remaining holes of former open pit mines can be filled with water, thus taking over various functions, ranging from industrial to recreational ones, or can be used for storing industrial waste or household waste. Such directions can be identified for the redevelopment of empty mining spaces (figure 5).

The global approach of ecological rehabilitation of areas affected by mining industry involves multiple reuse of the land. This means overlapping different uses and functions of land, as long as they are complementary [4].

Fig. 5. Possible reuse types for the remaining holes of open pits

The choice of the combinations of different possible reuse types for the open pits from Rovinari mining basin can be made quickly using the matrix from table 1 [2], [7].

Table 1. Possible combination between different types of reuse

Land / Water	Natural reserv.	Agricultural recultiv.	Forestry recultiv.	Grassing	Leisure and sports	Buildings
Naturalistic lakes	3	2	3	2	1	0
Sport fishing	2	3	3	3	1	1
Water manag. and irrigations	2	2	3	2	1	1
Water sports and recreation	1	2	2	2	3	1
Fish farming	0	2	2	1	0	0

3 very good; 2 good; 1 limited; 0 excluded

To create conditions for ecological rehabilitation, both the dumps and remaining holes resulting from mining must be prepared through stabilization works, land leveling and improvement (figure 6) [5], [7].

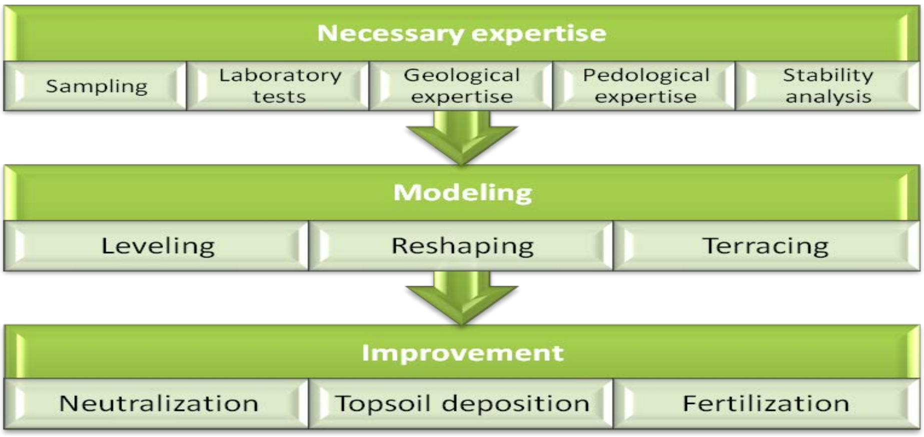

Fig. 6. Steps necessary to be taken in ecological rehabilitation works

In order to make a good decision on how to rehabilitate the land affected by open pit mining situated in Rovinari mining basin we've taken into account two of the most important aspects, namely the natural characteristic conditions (the surrounding landscape, the use of land in adjacent areas, the climate etc.) and the needs expressed by the population resident in the nearby towns and villages.

Depending on the natural conditions, 5 possible types of reuse of the land affected by brown coal exploitation in Rovinari mining basin were identified, which formed the basis for the realization of a questionnaire.

The assessment of the population's requirements for the reuse of the remaining holes and the rehabilitation of waste dumps from Rovinari mining basin was done taking into account the partial results obtained by conducting an online survey at a regional level, involving 109 persons. The questionnaire contains 5 choices of the type of reuse of the lands affected by mining in the Rovinari basin, taking into account the needs of the individuals and the local communities, the importance of the socio-economic development of the region and the restoration of the environment, all of which being seen from point view of the respondent [1].

After centralization, a hierarchy of population requirements was made regarding the type of reuse of the land affected by the 5 open pits from Rovinari mining basin, the results being presented in table 2:

Table 2. Hierarchy of population requirements

Rank	**Reuse type**
Tismana open pit	
1	Open pit lake (sport fishing, irrigations etc.)
2	Forestry
Rovinari open pit	
1	Waste deposit (household, municipal, industrial etc.)
2	Forestry

Pinoasa open pit	
1	Forestry
2	Waste deposit (household, municipal, industrial etc.)
Roșia de Jiu open pit	
1	Mining museum and cultural attractions
2	Forestry
North Peșteana open pit	
1	Open pit lake (sport fishing, irrigations etc.)
2	Forestry
3	Agricultural

Taking into account the options of the resident population in the areas where the open pits and waste dumps are located in the Rovinari mining basin, we have constructed a centralized table in which the final ecological rehabilitation variants of the 5 open pits and waste dumps are identified (table 3). In the last column, for the two careers involving the creation of lakes with different functions and forestation, the compatibility of the types of reuse is evaluated according to the matrix in table 1.

Table 3. Final choice for the ecological reuse type of the degraded lands from Rovinari mining basin

Open pit	**Remaining hole**	**Sterile dump and final slopes of the open pit**	**Compatibility**
Tismana	Filling the remaining hole with water (for sport fishing and irrigation)	Forestry	3
Rovinari	Ecological waste deposit (household, municipal and/or industrial waste)	Forestry	-
Pinoasa	Mining waste rocks deposit (from the overburden and sterile intercalations of Tismana open pit)	Forestry	-
Roșia de Jiu	Mining museum and cultural attractions	Forestry	-
North Peșteana	Filling the remaining hole with water (for sport fishing and irrigation)	Agricultural/Forestry	3

In general, the options expressed by participants in the online survey are well suited to what the concept of 'attraction or repulsion' of the territory represents to a certain type of reuse of a degraded land [8].

As can be seen from Tables 2 and 3, the first two options expressed by the population, with the exception of the North Peșteana open pit, were considered for choosing the final ecological reconstruction (or more correctly said land reuse) type.

In the case of North Peșteana, although the second option of the population indicated forest recovery, the authors considered, after consulting the local development plans, that the most suitable option for the ecological reconstruction of the waste dump is the agricultural one (the third option according to survey). In fact, the open pit is located in a meadow area (favorable to farming) and is surrounded by agricultural land. Forestry reconstruction will only target the final slopes of the open pit, above the lake level.

On the whole, we can see that the options expressed by the resident population create the premises for the reconstruction of the land degraded by mining by taking multiple functions.

In general, for the waste dumps and the final slopes of the open pits the resident population has opted for reforestation works, while for the remaining holes the options are slightly more diversified.

Thus, for Tismana and North Peșteana open pits, they have opted to create lakes, the main uses of which are to provide a water supply for irrigation of crops from neighboring lands in periods of precipitation deficiency and to allow sport fishing.

For Pinoasa and Rovinari open pits, the remaining holes will serve as waste disposal facilities. In the remaining hole of Rovinari open pit, which is favorably located near the towns and villages (outside the residential or sanitary protection areas but near the existing roads), it is proposed to set up an ecological landfill for domestic and municipal waste, while for the remaining hole of Pinoasa open pit, it is proposed to become a storage space for a part of the mining waste rocks from Tismana open pit (considering, of course, the exploitation program of the two open pits and the relatively small distance between them).

In the remaining hole of Roşia de Jiu open pit, the construction of an industrial museum is proposed, with the mention that other events such as open-air concerts can be organized in this space (such type of reuse was accomplished for the remaining hole of North Golpa open pit from Germany, currently known as the Ferropolis Museum, which functions as an industrial monument, theme park and exhibition area) [3].

The following ideas were taken into account for determining the final destination post-utilization of the surfaces:

- the necessity for integration of the new surfaces in the surrounding landscape;
- physical needs of the population concerning the land property;
- the morphology of the land and the exposure of the final slopes of the open pits and waste dumps;
- pedological characteristics of the soils;
- available water resources and the necessity for the restoration of the initial level of the underground water;
- costs of the necessary works;
- cultural needs of the local population.

On the basis of the above, figure 7 presents a sketch of the way in which the land, affected by brown coal exploitation, from Rovinari mining basin, after the productive activities cease, will be ecologically reconstructed and reused.

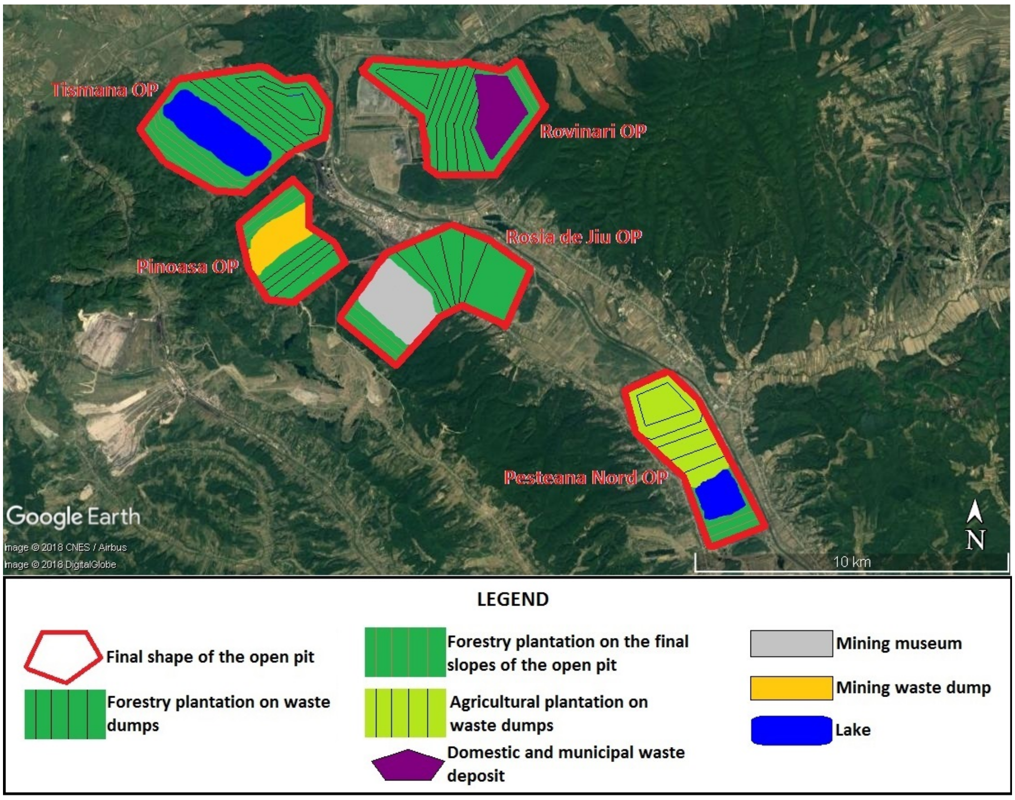

Fig. 7. Final configuration of Rovinari mining basin

6. CONCLUSIONS

The concept of ecological reconstruction of the mining affected areas in the Rovinari basin meets the following objectives of the national strategy for reconstruction of the mining areas, using the idea of sustainability:

- economical reconstruction and reuse of surfaces affected by open pit mining as big as possible;
- morphological and landscape reconstruction of the surfaces;
- creating lakes in the remaining holes;
- developing activities for the community in order to reuse the remaining facilities from the closed mining units;
- involving the community members for rehabilitation and reconstruction of the environment.

As a result, the proposals presented in this paper leads to a decrease of the danger of pollution of the environment in the analyzed area as well as to a rehabilitation of the environmental factors to a state as close as possible to the situation previous to mining, all in the context of sustainable development of the society.

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RESEARCHES CONCERNING THE POSSIBILITIES OF CAPITALIZATION THE PONDS TAILINGS FROM THE COAL PROCESSING PLANT COROEȘTI

CAMELIA BADULESCU [1]

Abstract: *The paper presents a synthesis of the researches undertaken to exploit the waste sludge from ponds at the Coroeşti plant in different fields of activity. The proposed goal was to fully process this residue, which until now is only usable in the field of building materials, but which, following the researches carried out, proved to be more than an industrial waste. Last but not least, the full utilization of this industrial waste reduces its impact on the environment, while at the same time reaping large areas of land in the natural circuit.*

Keywords:

1. INTRODUCTION

The tailings ponds are owned and operated by the Jiu Valley Coal Processing Facility - Coroesti Processing Plant, which is part of the National Company of the Coal Company in Petrosani, Hunedoara County.

At the Coroesti processing plant, due to the low inclination of the site, the solution was made for the construction of some "field" ponds, approximate 25 hectares.

The tailings pond no.I, put into operation in 1964, consists of two compartments A and B and it is situated in the meadow on the right west of the West and occupies a total area of 14 ha. At present, the amount of tailings stored in the first pond is about 3,300,000 tons.

Tailings I occupies an area of 10.8 ha, the amount of sterile slurry stored in this pond is about 2,000,000 tons. This pond came into operation in 1968.

2. PHYSICAL, CHEMICAL AND MINERALOGICAL CHARACTERISTICS OF STERIL STROM FROM U.P.COROESTI

Sampling was carried out on the surface of the two decanting ponds IA, IB and II.

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The 10 drillings were carried out at a depth of 3 m, taking samples from meter to meter. The ashes of the sterile slurry, along the drilling depth, are presented in table no.1.[1]

Table 1. The ash contents on drilling depth

Sample	Drilling depth (m)		
	1m	**2m**	**3m**
IA-1	53,55	54,20	39,99
IA-2	66,50	58,50	56,08
IA-3	54,18	57,70	47,51
IA-4	74,61	57,98	28,37
IA-5	23,31	27,47	44,01
IA-6	40,06	46,72	58,36
IA-7	69,79	67,40	53,44
IB-1	78,4	77,65	82,85
IB-2	78,65	78,25	66,95
II -1	69,22	80,02	75,68

The elemental analyzes revealed that this waste has a calorific value between 2110 and 2180 kcal / kg, which can be an advantage in advancing the idea of capitalizing these ponds.

Table 2 presents the petrographic composition of the sterile sludge from U.P Coroeşti which revealed a significant share of vitrinite and clayey minerals.

Table 2. Petrographic composition of tailings from U.P.Coroești

Name of petrographic component	Content(%)
Vitrinite with 5% exinite	40,23
Mineral clay substances	43,21
Iron mineral susbstances	16,89
Iron carbonates	0,56
Pyrite	0,85

Table no. 3 shows the physico-chemical parameters of the sterile sludge from U.P.Coroesti

Table 3. Chemical elemental analyses of tailings

Parameter	U.M.	Values
Volatile matter	%	14,40
Higher calorific power	kcal/kg	2180
Lower calorific power	kcal/kg	2110
Carbon	%	21,13
Hydrogen	%	1,5
Sulfur	%	0,62
Azote	%	0,32
Oxygen	%	3,30

Wet granulometric analyzes were carried out on the waste slurries taken from the two tailings ponds, the purpose of these analyzes being to determine the weight of the particle size - 0.040 mm, a class that can cause problems in the utilization of this material.

Referring to figures 1, 2 and 3 granulometric analyzes and ash content on granulometric classes for three samples taken from the two tailings ponds.[2]

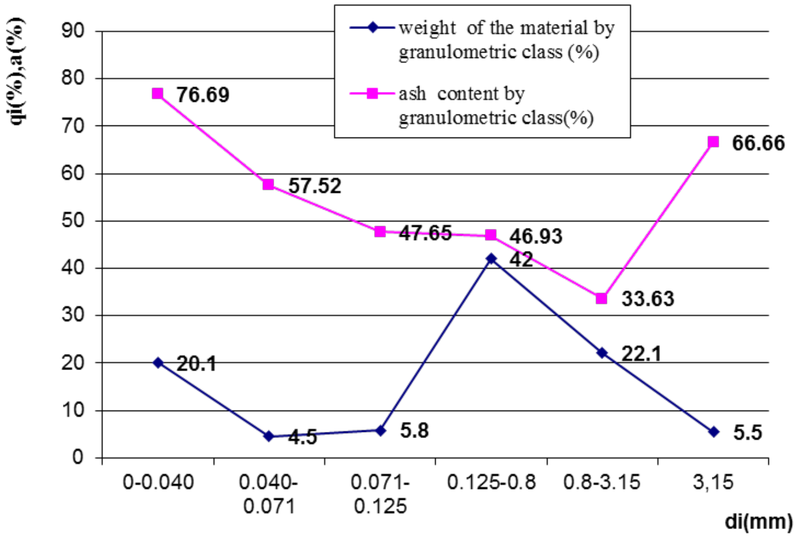

Fig. 1. The weight of the material and the ash content by granulometric class, pond I compartment A

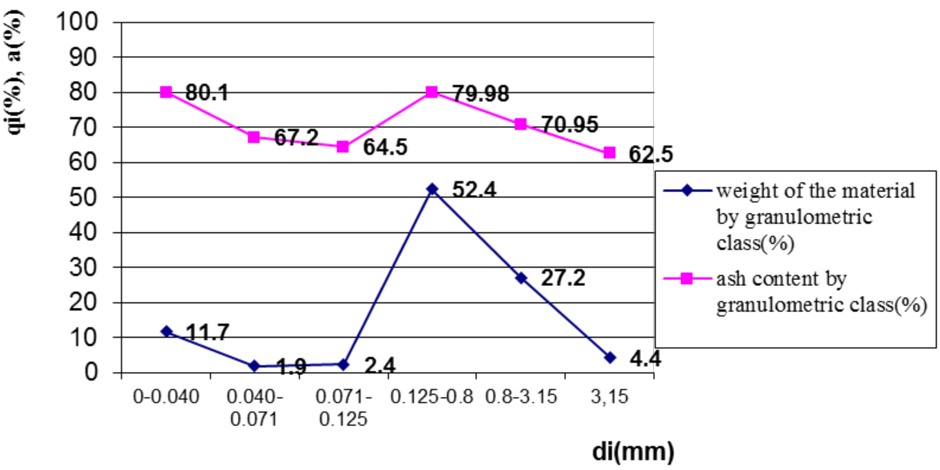

Fig. 2. The weight of the material and the ash content by granulometric class, pond I compartment B

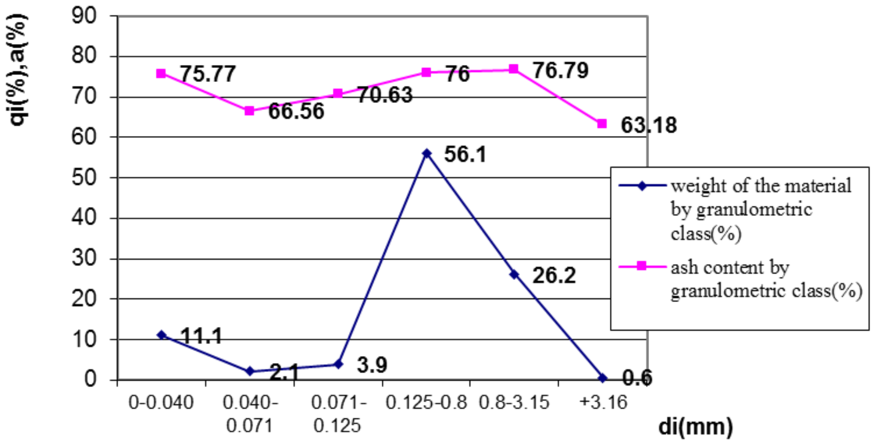

Fig. 3. The weight of the material and the ash content by granulometric class, pond II

Analyzing the samples taken from the tailings ponds, the following conclusions can be drawn:

- the ash content by granulometric classes ranges from 46,93% to 79,98%;
- the weight of the granulometric class +3.15 mm ranges from 0.6% to 5.5%;
- the weight of the granulometric class - 0.040 mm ranges from 11.1% to 20.1%.

3. POSSIBILITIES OF CAPITALIZATION THE PONDS TAILINGS FROM THE COAL PROCESSING PLANT COROEȘTI

3.1. Use of waste slurry from U.P.Coroesti in the manufacture of briquettes

Obtaining briquettes from waste slurry is possible, but it should be taken into account that this product is characterized by a low calorific value, implicitly a high ash content and very fine granulometry. To improve the calorific power and the resistance to transport and handling, there may be several solutions:

- addition of biomass (mainly sawdust - present in sufficient quantities in the area);
- the use of petroleum residues such as petroleum coke, petroleum sludge, etc.
- the use of a high calorific binder;
- lime addition - for the desulphurisation of combustion gases

Obtaining briquettes without heat treatment is preferable, mainly because of the lower cost of production. The location of modular lightening plant installations is possible in the immediate vicinity of the ash ponds, the silo scheme for sludge, biomass and lime, volumetric classification machines, homogenizers and presses.

The briquetting tests have focused on obtaining products that meet certain quality requirements in terms of:[5]

- compressive strength;
- calorific power;
- cohesion;
- chemical composition of combustion gases.

Experimental result

Starting from output previous researches unfurled as much on internal how much plan and international established several recipe in which varied material used-up weight and pressure of thing the effect on which have it in the of a corresponsive briquettes accordingly from viewpoint resistances, caloric power and compositions gas result in follows the burning.

In the table 4 is presented some among used-up recipe for the bricks manufacturing.[4]

Table 4. Recipes for briquettes using different materials

The compozition of some bricks	slurry (%)	coke (%)	molasses (%)	lime (%)	sawdust (%)
1	37,0	37,0	6	7	13
2	43,5	43,5	6	7	0
4	43,0	43,0	7	7	0
5	36,0	36,0	8	7	13
6	42,5	42,5	8	7	0
7	35,5	35,5	9	7	13
8	42,0	42,0	9	7	0
9	35,0	35,0	10	7	13
10	41,5	41,5	10	7	0
11	41,0	41,0	11	7	0
12	33,5	33,5	13	7	13
13	39,5	39,5	14	7	0

Analyse the resistances to pressure depending on the used-up blend composition (figure 4) indicates us the fact that to pressures of as far as 300kN briquettes have in composition sawdust (the recipe nr. 9 and 12) they have a resistance an erect maul than one in which sawdust absents ones. Also he ascertained that for the blends with sawdust the growth pressures of thing to across 300kN he don't produce a considerable growth resistances to pressure.[4]

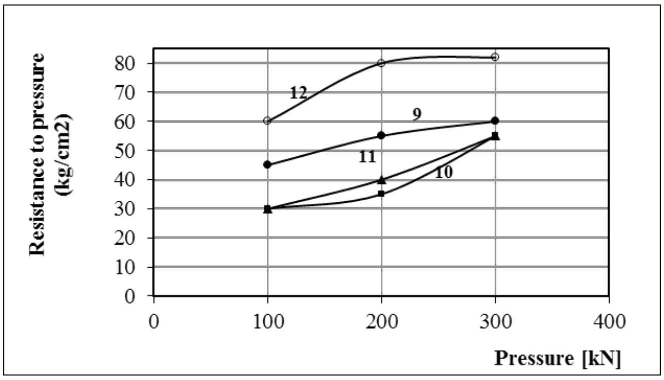

Fig. 4. Resistances to pressure depending on the used-up blend composition

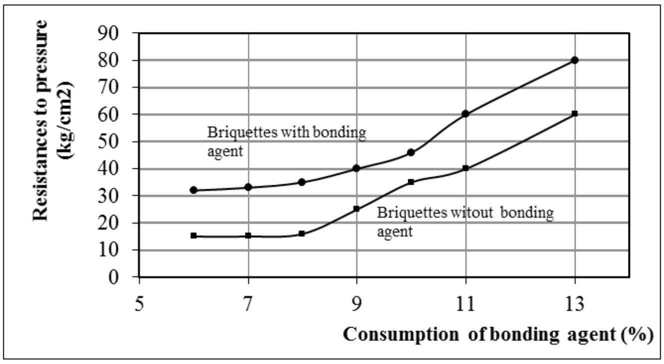

Fig. 5. Resistances depending on the consumption of bonding agent

Conversely, for bricks obtained from coal sludge, oil coke, lime and molasses the growth pressures has a positive effect about briquettes resistances but this thing leads to the considerable cost of production. Chart resistances depending on the consumption of bonding agent (figure 5) denote that for consumptions of feather to 8% registered an easy growth resistances to compression gift to consumptions across this value the briquettes resistance breeds significantly. Of a settlement optimum consumption of bonding agent is due to directs to the resistance to pressure, the resistance to cohesion, incident to appearance the costs of acquisition and transportation binding agent how much and technological appearance. In this sense he noticed that to consumptions of across 13% is produced a fluidization of materials, in the moment press to pressures of across 100kN, what leads to his transmigration and thus appear technological problems. Also is can noticed that the sawdust improves characteristics property of resistance for briquettes obtained to same consumption of bonding agent. The utilization of sawdust present the advantage that reduces the molasses consumption, he breeds the resistance to pressure, the index of cohesion and improves the process of ignition. Analyse, through Fast Vac., Recipes 12 and 13, I carry corresponding from viewpoint resistances to pressure and they have an index of erect cohesion, indicates us the presence of substance (table 5):[3]

Table 5. Substances in mixtures subjected to briquetting

Substance	Chemical compozition for brick no.12 (%)	Chemical compozition for brick no. 13(%)
SiO_2	14,1	17,0
C	56,8	57,4
Na_2O	0,317	0,243
MgO	0,436	0,457
Al_2O_3	7,85	9,95
P_2O_5	0,0377	0,0373
SO_3	6,03	5,27
Cl	0,0566	0,0273
K_2O	1,77	1,37
CaO	9,83	5,55
TiO_2	0,408	0,433
V_2O_5	0,119	0,0818
Cr_2O_3	0,0127	0,0173
MnO	0,0252	0,0206
Fe_2O_3	2,11	2,03
NiO	0,0336	0,0253
CuO	0,0111	0,00807
ZnO	0,0151	0,00824
Ga_2O_3	-	0,00232
As_2O_3	0,0160	0,0000445
Br	0,0142	0,0112
Rb_2O	0,00739	0,00780
SrO	0,0184	0,0152
Y_2O_3	0,00532	0,00386
ZrO_2	-	0,0122
Pt	0,00594	0,00525
Sume (%)	**100**	**100**

Is can noticed from assays values the reduced crown which content plough can pass able to boat. Also noticed the presence gallium and zirconium in the blends whit sawdust but breed contained of carbon. The utilization sawdust's leads to the growth bricks resistances obtained to same pressure of thing and same consumption of bonding agent. For bricks with sawdust the growth pressure of thing across 300kN don't leads to the considerable improvements resistances again for briquettes without sawdust a pressure of elder thing is absolute necessary. Breed the content treacly breeds the resistance briquettes obtained but an elder consumption of 15% creates technological problems. The sawdust improves the comportment to ignition and burns due to temperatures of ignition the low maul than oil cokes and coal sludge. For the storage and the commercialization obtained bricks from these blends are enforced sacking and the preservation in safe from places humidity. The flow sheet manufactured this guy of bricks is enough of simple from enforces the supplementary incident to costs the utilization heat carrier.

The presence agent desulphurization reduces the emissions of oxides of sulphur again the ash result, due to presences gypsums and contained very diminished crown difficult, is can utilized for the improvement soils.To bricks improperly from viewpoint of resistances to pressure they noticed fissure to bur.

3.2. Recovery of fuel from tailings ponds

Samples taken from the decantation ponds at different depths revealed significant variations in ash content. Also, the relatively high calorific power, respectively 2110kcal / kg, allowed the accreditation of the idea that it is possible to recover the fuel from the tailings ponds.

The waste slurry processing trials have focused on flotation and symptotic classification in the classical cone.

The flotation concentration tests have shown that, by applying a primary flotation and flotation cleaning, an energy coal with an ash of 40%, a 60.5% extraction by weight and a clean coal extraction can be obtained in the washed coal of 90%.

Symptomatic classification led to a 29% product, a 25% weight extraction, and a clean coal extraction in washed coal of 47.6%.

3.3. Use of waste slurry in the construction materials industry

The research undertaken in this direction aimed at obtaining products with characteristics comparable to those obtained from conventional raw materials. The following parameters were:

- Volumetric density below 1000kg / m^3;
- Large and uniform porosity;
- Compressive strength suitable for use in thermal and acoustic insulation works;
- Reduced cost.

Laboratory tests have been carried out in order to obtain optimal BCfA brick manufacturing receipts that corresponds qualitatively to the intended purpose.

The variation of the main qualitative parameters of BCfA bricks with the addition of sterile slag in their composition is shown in Figures 6, 7 and 8.[2]

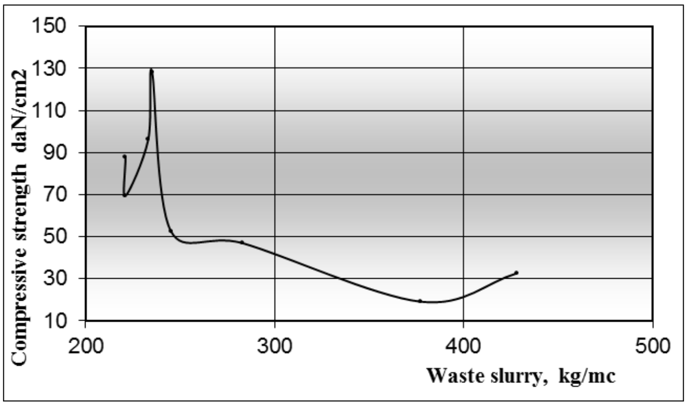

Fig. 6. The variation of the compressive strength with the amount of waste slurry in the composition

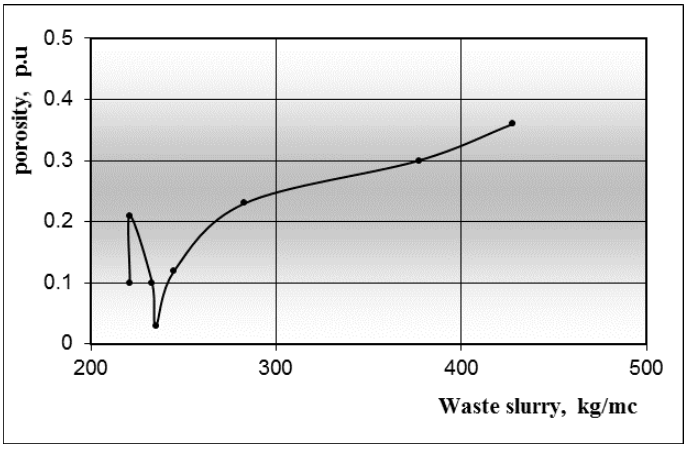

Fig. 7. Variation of porosity with the amount of slurry in the composition

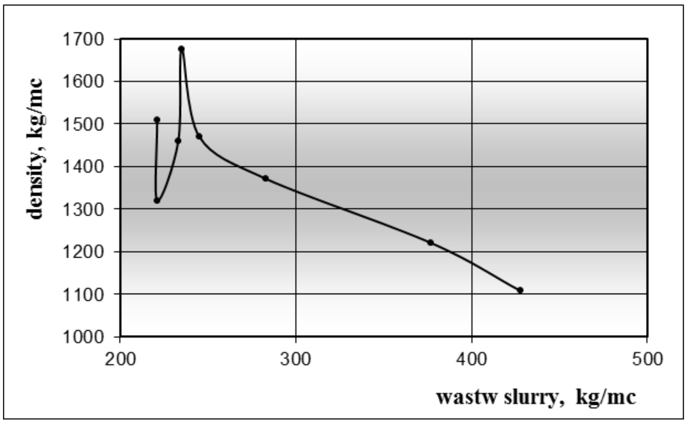

Fig. 8. Density variation in bulk with the amount of waste slurry in the composition

Various composite materials were used in the manufacture of these bricks: clay, waste slurry, thermoelectric power station ash, sponge, binder.

At a content of 15-20% sterile slurry, 30-40% of ash, 3-7% sponge and 7-10% binder, bricks with a compressive strength of 45daN / cm^2, a density of 700kg / m^3 and a porosity of 45-50%. These bricks can be used for sound insulation works, acoustic screens along highways, railways, etc.

4. CONCLUSIONS

The tailings ponds of U.P.Coroeşti occupy an area of 25 hectares, storing 5 million tons of industrial waste, well above the projected capacity of these warehouses;

The research carried out for the full recovery of this waste has been oriented in three distinct directions:

- Recovery of combustible mass by flotation or by symptotic classification with the obtaining of a recoverable product as energetic coal;
- Manufacturing of environmentally friendly briquettes using different industrial wastes.
- Valuation in the construction materials industry by producing bricks with qualitative characteristics suitable for use in sound insulation works, acoustic screens, etc.;

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PROBABILISTIC APPROACHES IN TUNNEL DESIGN

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Abstract: Usually, tunnel final linings are designed according to specific criteria and safety levels required by various codes – Eurocodes for projects located within EU. These codes are mainly applicable in conventional structures, where variability is extremely reduced, and a deterministic approach is largely used. On the contrary, the loads on the final lining of tunnels result from the interaction of the rockmass, temporary support and the final lining. These loads are subjected to a higher degree of uncertainty due to the high variability of the geomechanical parameters of the rockmass. On the other hand, materials used for the lining (shotcrete, concrete, steel), present a higher variability than similar materials used in surface construction, due to non-uniformities during the underground construction process. This paper investigates the variation of the final lining loads using Monte Carlo simulations performing a probabilistic analysis using Rocscience's RS2 Finite Element Software. Selection and validation of the Probability Density Functions (PDFs) for the input parameters is realised using @RISK add-on to Excel program.

Keywords: *tunnel desig, probabilistic approach, Monte Carlo simulations, FEM, uncertainty, PDFs;*

1. INTRODUCTION

The considerable uncertainty of the geomechanical parameters has led to conservative designs of tunnel linings with "hidden" safety factors (i.e. the empirical methods for the estimation of tunnel loads), and the very conservative assumption of complete de-activation of all temporary supports.

When considering the statistical distribution of input parameters, we have to select Probability Density Functions (PDFs) which best describe the population of a specific parameter. In geomechanics, there are difficulties in measuring properties such as rock stresses, rock modulus or rock strength, and we have to select the values for input parameters of PDFs based on the following criteria:

- Intrinsic uncertainty;
- Experimental uncertainty;

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- Heterogeneity/ Spatial variation;
- Time variation.

2. RS2 MODEL TO STUDY MATERIALS PARAMETER VARIABILITY ON LINING BEHAVIOUR

Considering the given design criteria, the probability of failure is given by the grey areas in Fig. 1. By combining the probability of failure with the consequences of failure, it would result in the risk of the design, and thus, we can evaluate if this risk is acceptable. There is always some residual risk remaining even at the final design stage (the darker grey area on Figure 1), and this risk should be mitigated.

Uncertainties in the estimation of geomechanical parameters arise from the difficulty in measuring these characteristics, and the measurements process is subjected to errors due to the sampling process, sample preparation or sensitivity and calibration of the measuring devices. As a project develops, this uncertainty is reduced by acquiring repeated measurements.

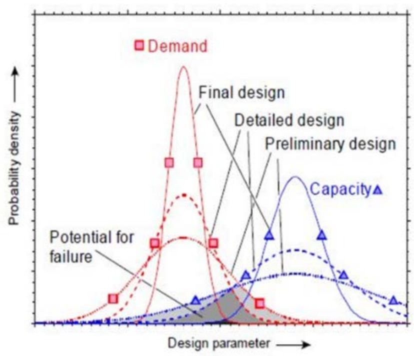

Fig. 1. Demand - capacity PDFs for tunnel lining design

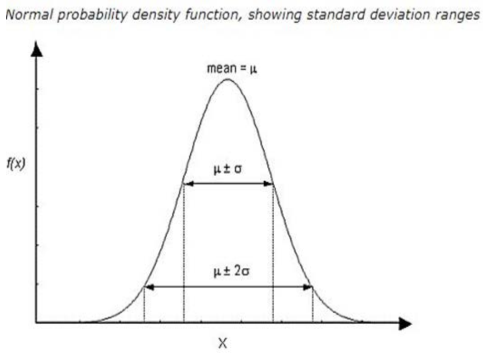

Fig. 2. The normal probability density function

Heterogeneity or spatial variation is an inherent property of the natural materials and rockmass implicitly, and rockmass property will vary within a rock unit. Thus, a failure mechanism will affect more or less severely various locations along the rock unit.

In order to determine the parameters of the Normal Distribution for each considered parameter, the Three Sigma Rule of Thumb has been used, where we estimated the highest conceivable value (HCV) of the random variable, and the lowest conceivable value (LCV). @RISK add-on for Excel has been used to derive the normal distribution for the input parameters. Fig. 3 and Fig. 4 show an example of a graphic representation of the normal distributions for both intact and residual Young's Modulus.

In all RS2 models, a Truncated Normal Distribution has been used – which is considered as the mean +/- 3 standard deviations. Fig. 2 is an example of a truncated distribution, with mean +/ - standard deviations.

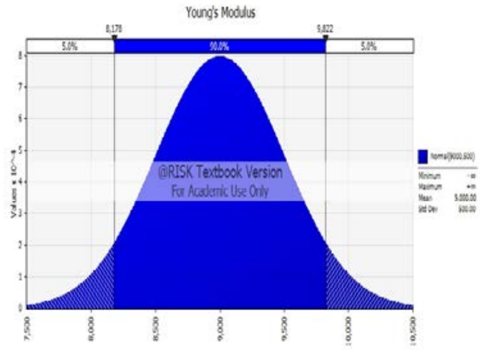

Fig. 3. Young's modulus normal distribution

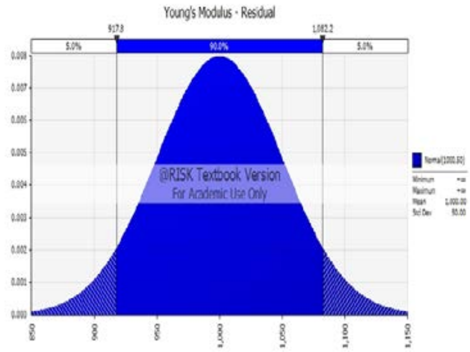

Fig. 4. Young's modulus (residual) normal distribution

2.1. Model Setup and Stress Path

A simple tunnel with an invert has been embedded into the rockmass, and boundary conditions have been specified. An initial stress field of sigma one = 8 MPa, sigma three = 6 MPa, sigma z = 6 MPa has been applied to the model and a plane train analysis is performed.

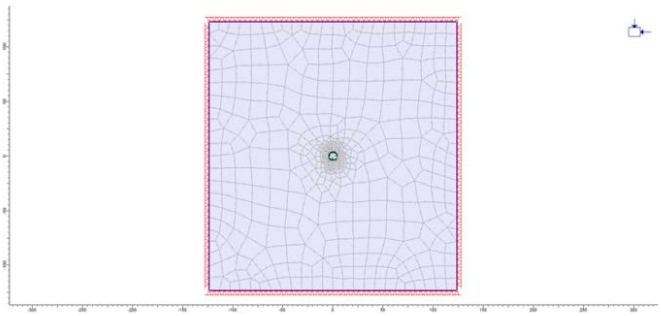

Fig. 5. RS2 model

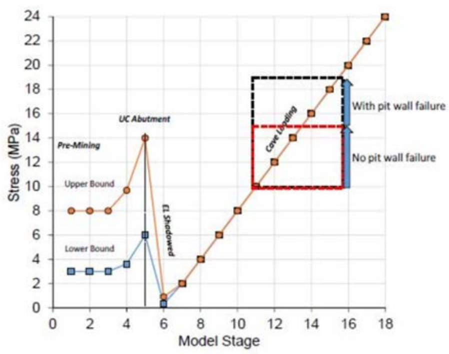

Fig. 6. Applied stress path

The general model used in this probabilistic design is represented in Fig. 5. Subsequently, a number of stress stages are applied to the model, corresponding to the loading-unloading-loading stress path for a tunnel located at Extraction Level within a block caving mining drawbell/ drawpoint – Fig. 6.

A number of 1000 samples of input parameters are generated per run, using Monte Carlo or Latin Hypercubic sampling methods, and then each realisation is run independently. At the end of 1000 runs, results are assembled together as normal distributions.

2.2. Model 1 - Elastic-Perfectly Plastic Behaviour (Hoek-Brown Parameters Peak = Residual) + Dilation – Probabilistic with Monte Carlo Sampling

This analysis considered that the rockmass behaves elastic-perfectly plastic and the failure is given by a Hoek-Brown criterion. Input parameters are presented in Table 1, and a Monte Carlo sampling technique has been used to generate sets of parameters for each realisation from the given normal distribution.

Table 1. Input parameters for model 1

Variable Type	Material/Joint Name	Property Type	Distribution	Mean	Standard Deviation	Min	Max
Material Property	Softzone	Young's Modulus	Normal	9000	500	7500	10500
Material Property	Softzone	Intact Compressive Strength	Normal	14	1.166	10.502	17.498
Material Property	Softzone	Hoek-Brown mb parameter (peak)	Normal	13	1	10	16
Material Property	Softzone	Hoek-Brown s parameter (peak)	Normal	0.95	0.0166	0.9002	0.9998
Material Property	Softzone	Hoek-Brown a parameter (peak)	Normal	0.55	0.0166	0.5002	0.5998
Material Property	Softzone	Dilation Parameter	Normal	10	1.666	5.002	14.998
Material Property	Softzone	Young's Modulus	Normal	9000	500	7500	10500

Table 2 contains equivalent characteristics in the combined liner – steel arches (parameters are given in Table 3) and shotcrete/ concrete (characteristics presented in Table 4.

Table 2. Equivalent parameters for combined liner: concrete + steel arches

Liner Type	Reinforced Concrete
Equivalent Young's modulus	36927.4 MPa
Equivalent thickness	0.407118 m
Poisson ratio	0

Table 3. Reinforcement properties of steel arches

Type	I-beam (HP): HP360 x 152
Spacing	1 m
Section Depth	0.356 m
Area	0.0194 m2
Moment of inertia	0.000437 m4
Young's modulus	200000 MPa
Poisson ratio	0.25
Compressive strength	400 MPa
Tensile strength	400 MPa

Table 4. Concrete properties

Thickness	0.355 m
Young's modulus	30000 MPa
Poisson ratio	0.15
Compressive strength	40 MPa
Tensile strength	3 MPa

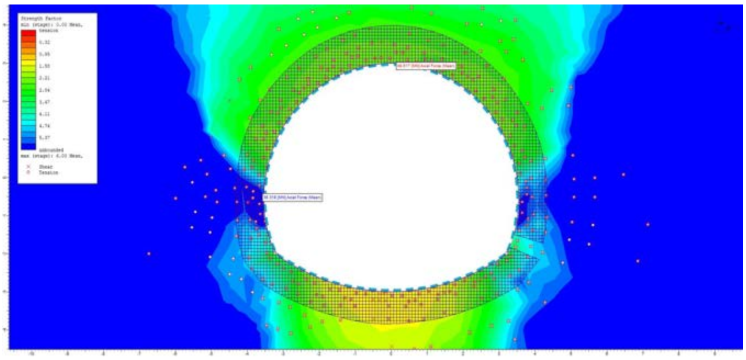

Fig. 7. Axial forces in last stage and strength factor in rockmass

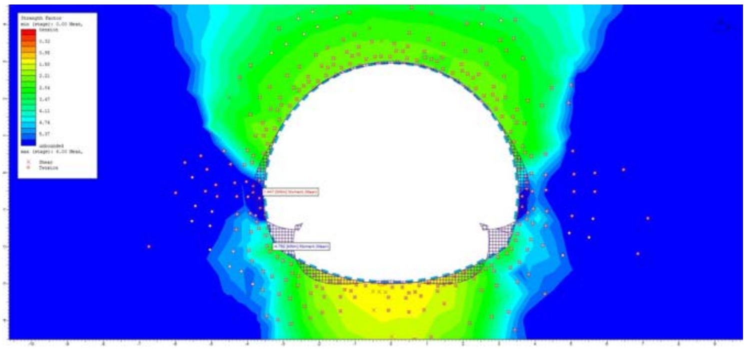

Fig. 8. Bending moments in last stage and strength factor rockmass

Results were calculated for each stage of the stress path – a total number of 18 stages were considered in the analysis.

Axial forces are represented for the last stage (highest load) in Fig. 7, whereas bending, movements acting on the combined liner are sown in Fig. 8.

As mentioned previously, results form the 1000 realisations are compound together into a normal distribution – the user has the option to plot results for each parameter around the mean of the normal distribution.

As an example, the Strength Factor in the rockmass defined as the ratio between applied stresses and rock strength is shown in Fig. 9 and Fig. 10:

Fig. 9 – for the mean +3 standard deviations, corresponding to the Best-Case Scenario; rockmass around the tunnel still present some resistance as the Strength Factor is over unit;

Fig. 10 – for the mean -3 standard deviations, corresponding to the Worst-Case Scenario; rockmass fails around the tunnel, with Strength Factor reaching values of 0.32.

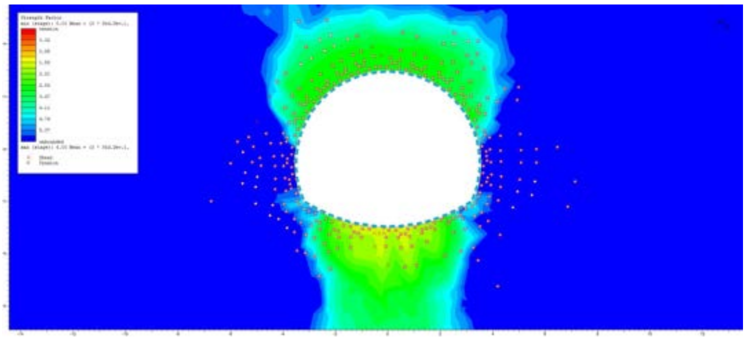

Fig. 9. Strength factor in rockmass for mean + 3 standard deviations

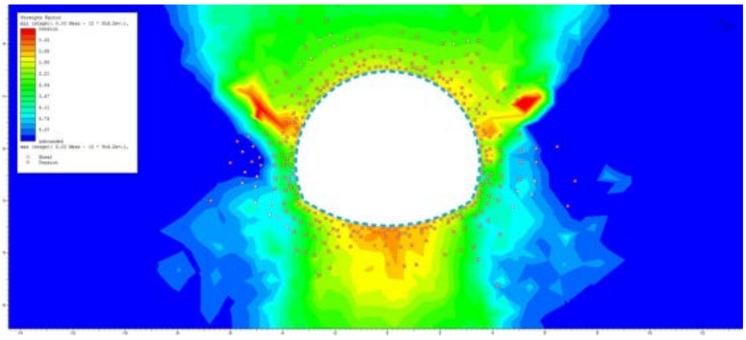

Fig. 10. Strength factor in rockmass for mean - 3 standard deviations

2.3. Model 2 - Model 2 - Elastic-Plastic with Strain Softening Behaviour (Hoek-Brown Parameters Peak ≠ Residual) + Dilation – Probabilistic with Latin Hypercube Sampling

This analysis took into account an elasto-plastic rockmass, with a strain softening post-peak behaviour. Table 2 contains input parameters for this model and the sampling technique used is Latin Hypercube.

Axial forces are represented in Fig. 11 along with the Strength Factor in the rockmass and Fig. 12 shows the bending moment applied to the combined liner.

Table 5. Input parameters for model 2

Variable Type	Material/Joint Name	Property Type	Distribution	Mean	Standard Deviation	Min	Max
Material Property	Softzone	Young's Modulus	Normal	9000	500	7500	10500
Material Property	Softzone	Intact Compressive Strength	Normal	14	1.166	10.502	17.498
Material Property	Softzone	Hoek-Brown mb parameter (peak)	Normal	13	1	10	16
Material Property	Softzone	Hoek-Brown s parameter (peak)	Normal	0.95	0.0166	0.9002	0.9998
Material Property	Softzone	Hoek-Brown a parameter (peak)	Normal	0.55	0.0166	0.5002	0.5998
Material Property	Softzone	Hoek-Brown mb parameter (residual)	Normal	1.8	0.166	1.302	2.298
Material Property	Softzone	Hoek-Brown s parameter (residual)	Normal	0.9	0.0166	0.8502	0.9498
Material Property	Softzone	Hoek-Brown a parameter (residual)	Normal	0.45	0.0166	0.4002	0.4998
Material Property	Softzone	Dilation Parameter	Normal	10	1.666	5.002	14.998

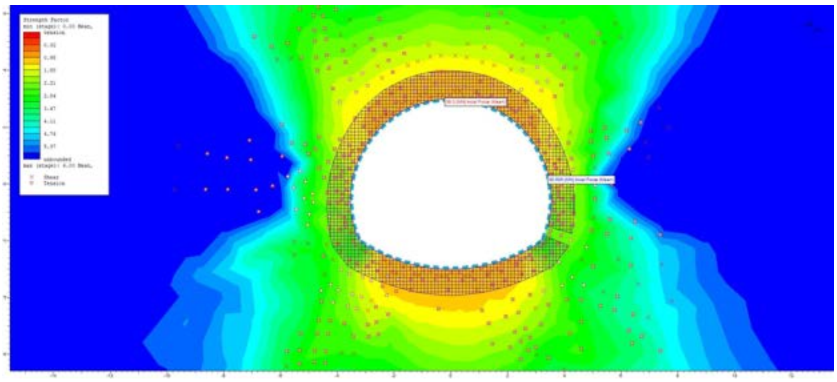

Fig. 11. Axial forces in last stage and strength factor in rockmass

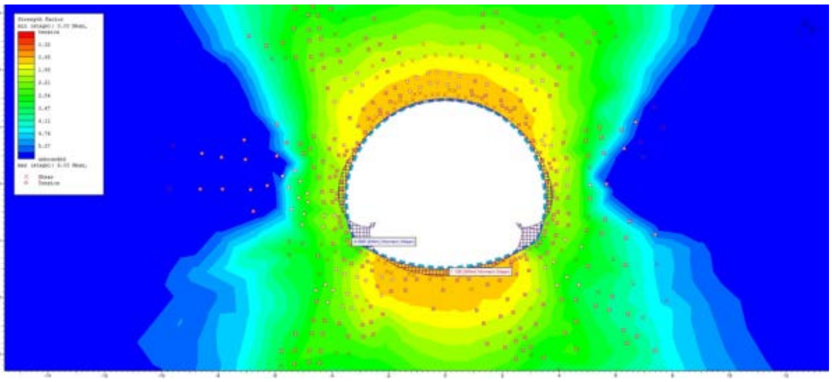

Fig. 12. Bending moments in last stage and strength factor in rockmass

3. CONCLUSIONS

Uncertainty in the estimation of input parameters for a tunnel lining design can be overcome by using a probabilistic approach. Using Monte Carlo simulations, implemented in Rocscience's RS2 software, axial forces (mean) and bending moments (mean) could be determined for two models with elastic-perfectly plastic and strain-softening behaviours and characterised by Hoek-Brown failure criterion.

The design engineer has a tool to predict tunnel liner/ support behaviour for various scenarios, from the Base-Case Scenario ($\sigma + 3\mu$) through the Most Probable Scenario (σ), to the Worst-Case Scenario (($\sigma - 3\mu$).

Consideration of uncertain parameters for the liner and the derivation of the reliability index of the system rockmass – liner are the next steps of this analysis.

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EFFICIENCY OF INDUSTRIAL VENTILATION INSTALLATIONS

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Abstract: Effective and efficient air distribution is an important aspect of industrial ventilation. When the air flows through a ventilation column, the pressure required to push or draw air through it, depends not only on the internal frictional force but also on the dimensions, length and shape of the pipe, the roughness of its walls, the nature of the obstructions inside, speed and air density. The air movement introduced into ventilated rooms can be controlled and conducted as direction and sense of movement. In rooms, overpressure or under pressure may be created as necessary. Designing and building an individual ventilation system, should harmonize comfort requirements with the user's ventilation system management, without adversely affecting other system functions.

Keywords: *ventilation, optimization, efficiency;*

1. INTRODUCTION

The quality of the environment in which the staff perform their activity has a complex influence on them, both in terms of microclimate conditions and in labour productivity.

For many categories of premises, where significant disasters occur (production rooms, laboratories, etc.), the quality of the environment cannot be guaranteed only by the heating system. In order to remove toxic odours, there is a need for a "controlled" introduction of airflow. The nature and amount of harmful emissions, their mode of propagation, the building system of the enclosures, the values at which indoor air parameters are prescribed for comfort or technological reasons, the admissible limits to

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which the concentrations of various harmful substances must be reduced, have led to the use of a wide range of industrial ventilation facilities.

Industrial ventilation systems have a great diversity in terms of composition, (Doru C., et al., 2013) equipment fitting, component type, size of installations according to the volume of air flow rates, thermal (heating or cooling) power and generated pressures, as well as the way of air exchange in rooms, the temperature, pressure and humidity levels achieved in the rooms.

The type of building to which an industrial ventilation plant is intended is given its specific imprint on the installation, in particular through the solution adopted, the technical design (appearance, route, leakage, parameter assurance, noise level, automation, operation and maintenance etc.).

Automatic regulation installations for industrial ventilation facilities ensure that the indoor air parameters (temperature, relative humidity, air speed, CO_2 concentration) are preserved at any time of the year. Automatic adjustment is required for economic reasons, but also because manual adjustment of various parameters is not possible. Automation installations regulate the heat flow (hot / hot water, chilled water, steam) that feeds the heat exchangers of the air handling units (heating batteries, cooling batteries) or the airflow rate of the installation (fresh air, air recirculated, exhaust air).

2. APPLICABLE VENTILATION SYSTEMS

The adopted ventilation system must take account of the technological process, (Rădoi F., et al., 2016) density of sources, and propagation of harmful agents and the intensity of harmful agent’s release.

Systematic natural ventilation – in case of heated workshops without a release of noxious vapours, gases or dust with high heat releases and less releases of moisture, mainly applied in the form of mixed ventilation or along with other systems.

General exchange mechanical ventilation – applied when it occurs a release of harmful substances and the systematic natural ventilation is insufficient.

Local exhaust ventilation – used in order to improve working conditions in certain areas adjacent to sources of heat, strong radiant sources or to prevent entry of cold air through exterior doors.

Local air intake ventilation - when there are concentrated sources of harmful releases and general ventilation is insufficient even in large volumes of air.

Local absorption and exhaust ventilation - for example in industrial ablutions.

Emergency ventilation - automatically turns on in case of large accidental releases of harmful substances occurrence as a result of technological equipment failures.

Industrial air-conditioning- is required by the manufacturing processes, the need for precise conditions, in case of high precision processing, testing, and calibration.

3. OPTIMIZATION OF INDUSTRIAL VENTILATION INSTALLATIONS

The problem of industrial ventilation has risen due to the serious pollution problems of both the industrial areas (and their surrounding areas) and the industrial premises. It is obvious that before addressing an industrial ventilation study, the question is whether there is no simpler means of suppressing the causes of pollution or of reducing pollution by modifying the production process or the design of the industrial plant. It is preferable to treat the causes that lead to pollution and thus to eliminate it even from the design, and only when this is not perfectly possible, it is necessary to limit the effects of the pollution.

In order to be able to choose the correct ventilation system, (Alexandru Cristea, 1971) a complete analysis of the workplace to be ventilated must be carried out, so that the solution chosen to not only fix the problem of the exhaust, but also to be well received by the user, respecting the thermal comfort of it.

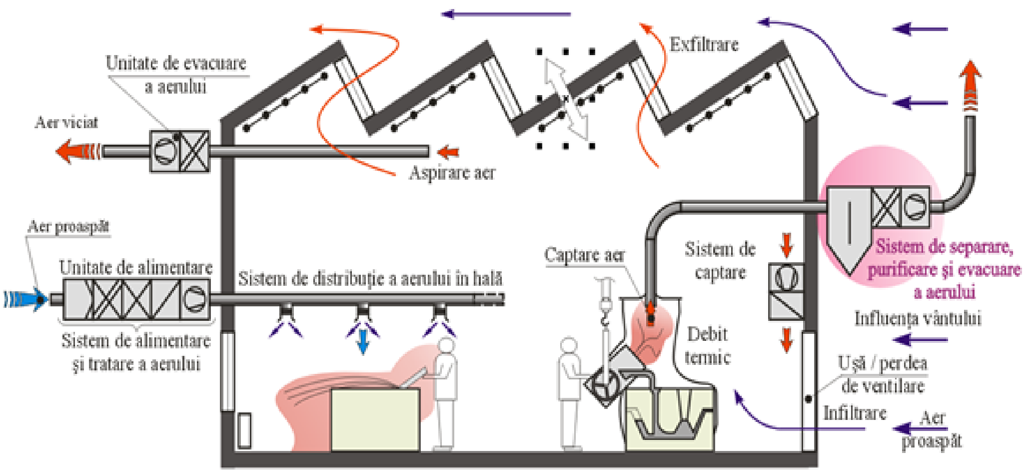

Fig. 1. Schematic diagram of an industrial enclosure

Thus, in an industrial area, the comfort of the workplace is influenced by the following factors:

- the presence of an air stream;
- an acceptable temperature gradient;
- soil temperature (too low or too high);
- the existence of an asymmetric radiant heat field, due to the presence of cold windows, heat sources only by one part of the operator's body or relative humidity level.

Choosing an industrial ventilation solution can be done by completing the following sequence of steps:

- clear definition of the building and its working stations, (Matei, I., et al., 2000) the type of industrial process being carried out, the personnel employed, the environmental restrictions, the temperature and the conditions for keeping the building in good condition;
- determination and classification of sources of pollution, their physical and chemical characteristics;
- the choice of the technical solution for capture and ventilation, considering: the possible evolutions of the industrial process and the changes that these developments can bring with regard to the ventilation system and the possible incompatibilities between different pollutants (e.g. dust and humidity, acids and bases, etc.) that require their separation;
- determination of parameters (air velocity, flow, heating) and calculation of the installation (determination of losses, load, diameter, installed power, etc.), choice of circuit elements (air inlets, required piping, fans, automatic, etc.), the physical location of the component parts, commissioning, reference values, maintenance;
- the ventilation scheme adopted must ensure that the air moves in the sense of harmful propagation;
- the collection and disposal of harmful substances at the site where they occur (use of local absorption plants in the case of concentrated poisons or the provision of emergency facilities in case of accidental leakage of toxic substances), in order to avoid their spread;
- introducing fresh air as close as possible to people's work area, respectively the ventilation system ensures uniformity of air parameters throughout the room in order to avoid clutter of harmful substances;
- use of overpressure or depression to limit the spread of noxious substances in or from other rooms or to avoid cold air drafts.

The selection and sizing of air intake and outlet holes, (Olga Bancea, 2009) is very important to ensure comfort conditions or working conditions and production processes and has two stages:

- ensure a good air circulation in the room so that air can be treated at all points, there are no areas where the air stagnates, no overheating air, air movement will not lead to the spread of noises, etc. The movement of air in a room takes place depending on the location of the inlet and outlet holes. Movement of air must be done at the same time, in the same way as the natural movement of the particulates (gases, vapours, dust) released. For heavier particles than air, evacuation will take place in the lower part of the room, for lighter particles at the top.
- the actual choice of the types of air inlet and outlet pipes is made considering the type of building (civil, industrial), the aesthetics of the room, the location of the machinery and the machinery. Depending on the amount of air flow calculated, the size of the room (length, width and especially height), type of air jet (isotherm, hot / cold non-isotherm), a number of air ducts of a certain type are chosen; or of two constructive types. Based on the chosen constructive type and the geometric dimensions (the distance between two adjacent holes, the height of the mouth from

the floor), the kinematic (jet air velocity at the work area / stay, the air velocity in the plane of the discharge mouth) / cold, temperature difference between room air and jet) and jet type (with the influence of the ceiling, without the influence of the ceiling), based on the diagrams or calculation programs of the manufacturing companies, determine the size of the discharge opening type. The choice of drain holes is simpler because the suction speed damping is inversely proportional to the square of the speed and the influence of the movement in the suction plane is no longer felt at distances greater than 2De. (De is the equivalent diameter of the suction mouth). The suction holes can have airflows, as a rule, up to 2000 m^3. Their dimensioning is also based on the room noise level. For social-cultural buildings, the air velocity in the plane of the suction mouth is v = 2-3 m/s. For industrial buildings, usually the speed is v = 3-5 m/s.

The local suction installations with the air velocity generate a limitation of the spread of the hazards, while at the same time ensuring the minimum openings necessary for the development of the technological processes. The devices used must ensure that the release is as complete as possible, do not obstruct the production process and allow the worker to be in a normal position so as not to be between the source of the harmfulness and the aspiration opening. These installations are made up of the capture device, air duct and fan. Devices for the capture of harmful substances in the immediate vicinity of the harmful outbursts may be: open, semi-closed or closed.

Fume cupboards are local aspiration devices located above, sideways or under sources. (Niculescu, N., et al., 1982). *Figure 2* shows the main types of hoods.

- The classic fume cupboard (Figure 2a) depending on the source of the source of the hazards, can be made with a square, circular or rectangular suction section. Its edges must exceed the perimeter source with (0,3 ÷ 0,4) y, where y represents the distance from the source. In order to smooth out the speed in the suction section, the opening angle of the cupboard $\alpha \leq 60$ ° and at the bottom a levelling band with the width (0,1 ÷ 0,2) y can be mounted at the bottom;
- The fume cupboard placed near the wall or above the furnace door (Figure 2b) limits the draft air suction and is not influenced by the direction of air movement in the enclosure;
- The compartment fume cupboard (Figure 2c) is used for sources of long-range hazards, each compartment being provided with individual evacuation;
- The central and peripheral suction fume cupboard (Figure 2d, e) is used for working benches with different sizes and the surface of the source is variable;
- Folding fume cupboard (Figure 2f) allows to change the distance from the source and manipulate the parts and materials with transport devices (tread beams) by rotating the capture device 90 °;
- The telescopic fume cupboard (Figure 2g) allows, depending on the required technological operations, a change in the distance from the suction plane;
- Accumulator fume cupboard (Figure 2h) used for accidental leakage of high-rate hazards, allowing for momentary capture and evacuation.

The air captured at the workplace must be evacuated to the outside and, if necessary, cleaned according to the regulations in force. The drainage is done using the tubing. Methods for calculating the duct and the ventilator are based on the determination of the air flow resistance in the ducts and the definition of the ventilator operating conditions (flow, pressure, etc.). In general, piping dimensioning results as a compromise between economic restrictions (investment, operation - operation), standardized diameters, load losses, minimum transport speeds, the presence of corrosive pollutants, etc. The air velocity in the piping should be chosen for each installation, depending on the nature and properties of the pollutants. Transport speed is an essential factor for dust-containing exhaust systems, it must be above a minimum level to avoid dusting and time-blocking of the piping. It is even greater as the mass of particles is higher.

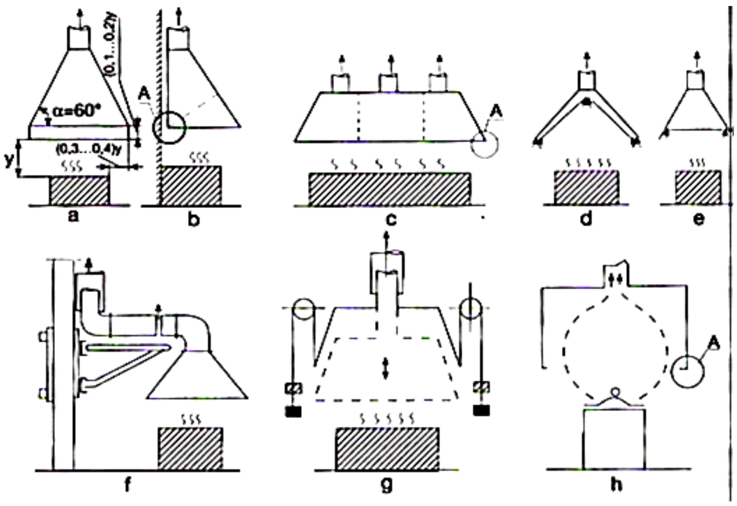

Fig. 2. Types of hoods

4. CONCLUSIONS

1. Industrial ventilation systems aim to ensure the conditions of air purity and microclimate corresponding to human activity and the nature of the technological process. The fulfilment of these requirements contributes to the maintenance of the work capacity, the elimination of the professional illnesses, the increase of labour productivity, the quality of the products, etc.

2. When designing the local suction devices, the following factors shall be considered in order to determine their type, shape and dimensions: the shape and location of the machinery; nature and manner of deployment of technological processes; nature, quantity and mode of generation of harmful substances; the dimensions and constructional shape of the production rooms.

3. The main sizes involved in defining ventilation and air conditioning systems are: air pressure, air speed, temperature and humidity.

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EFFICIENCY OF COMPLEX VENTILATION NETWORKS

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Abstract: The first measure for ensuring optimal occupational health and safety conditions in underground minerals exploitation is the achievement of proper ventilation (Teodorescu C., et all, 1980). For ensuring proper ventilation of each mine working, there is imposed the optimization of air flow repartition in each branch of the network, fact which involves the mine's entire ventilation network solving (Hargreaves D.M., et all, 2007). In hard coal exploitation, opening, preparation and exploitation works undergo a nonlinear continuously and differentiated process of specific aerodynamic parameters degradation. Following the changes in time of aerodynamic parameters of mine workings, specific ventilation parameters also change, leading to the ventilation network's deviation from the aerodynamic point of view, compared to the standard situation (Patterson A. M., 1992). The ventilation network's deviation is directly proportional to costs required for air circulation and inversely proportional to the efficiency of the ventilation network's aeration. In order to assess the efficiency of ventilation networks (Băbuţ, G.B., and Moraru, R.I., 2018), a new parameter has been introduced, namely the ventilation network's standard deviation. In this paper is presented the theoretical basis and the determination of the standard deviation applied for Lupeni mine unit ventilation network.

Keywords: *efficiency, modelling, software, solving, ventilation, ventilation networks*

1. LUPENI MINE UNIT VENTILATION NETWORK

Lupeni mine unit is equipped with two main ventilation stations: Shaft 1 East and Central Rising.

Underground mine workings are ventilated under the depression of the Main ventilation station Central Rising, fitted with two axial fans type VOKD 1.8.

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Underground mine workings which are ventilated under the depression of the Main ventilation station Shaft 1 East is equipped with two axial fans type VOD 3.0.

Fresh air entrance in underground is performed through 5 mine workings: Stefan shaft, shaft no. 12, shaft with skip, coast gallery horizon 650 and auxiliary shaft south.

Central Rising and Shaft 1 East circuits are extended over 5 horizons: horizon 300, horizon 360, horizon 400, horizon 480, horizon 650.

2. LUPENI MINE UNIT VENTILATION NETWORK SOLVING

For solving the ventilation network of Lupeni mine unit was used VENTSIM Visual Advanced software, designed and developed in Australia.

A number of 386 junctions and 481 branches have been inserted into the software's database. Figure 1 presents the 3D spatial ventilation network of Lupeni mine unit.

After the ventilation network's solving (Cioclea D, et all, 2012; Cioclea D, et all, 2014; Gherghe I., 2004), the following results have been obtained:

Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel II was 3.2 m^3/s; Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel III was 3.2 m^3/s; Air flow at the level of the longwall with undermined coal bed no. 11, seam 3, block V, was 4.0 m^3/s; Air flow at the level of the longwall no. 3, seam 3, block V, was 3.7 m^3/s; Air flow at the level of the longwall no. 2C, seam 3, block V, was 6.6 m^3/s; Air flow at mine level was 83.7 m^3/s; Air flow at the level of the main ventilation stations was 85.4 m^3/s.

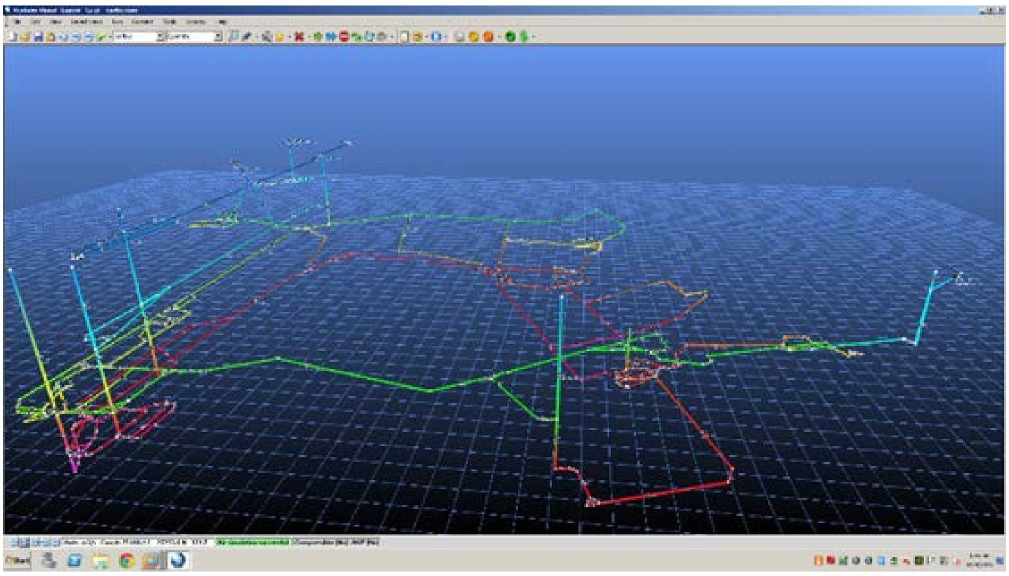

Fig. 1. Lupeni mine unit ventilation network in 3D system

3. METHODS FOR DETERMINING THE VENTILATION'S EFFICIENCY

For the classification of ventilation networks in terms of efficiency (Cheng J., et all, 2010; Cheng J., et all, 2011) are used several methods, namely: Equivalent orifice method, Ratios method, Temperament method.

3.1. Equivalent Orifice Method

The equivalent orifice of a mine is a ventilation parameters using which there may be characterized the ventilation capacity and it represents a fictional orifice A, performed into a thin wall, through which at a pressure difference on the two sides of the wall equal with the mines depression "h", will be circulated the same amount of air Q as the one circulated through the mine.

3.2. Equivalent Orifice Method

This method is characterized by the efficiency of the mine's general ventilation and takes into account the size of ratios:

$$\frac{Q_{sc}}{Q_{ef}} \text{ and } \frac{h_{ef}}{h_t} \tag{1}$$

in which:

Q_{sc} - air flow short-circuited in underground, m^3/s;
Q_{ef} - air flow which ventilates the work fronts, m^3/s;
h_{ef} - depression of the mine, determined by measurements, N/m^2;
h_t - theoretical depression of the mine, determined by calculation, N/m^2.

3.3. Temperament Method

In order to classify the manner in which a mine working's ventilation is achieved is used the T temperament term. Temperament represents the easiness with which the fluid passes the mine working.

4. STANDARD DEVIATION

Underground hard coal exploitation involves the performance of a complex of opening, preparation and exploitation workings in order to extract and transport the useful minerals to the surface. Once with the increase of the mine workings usage, their aerodynamic parameters negatively change, having severe consequences from the point of view of air flowing on their alignment. The degradation in time of aerodynamic parameters of mine workings leads to the change of the ventilation network's aerodynamic parameters. The change of aerodynamic parameters of mine workings in relation with the initial value represents the ventilation network's deviation (Cioclea D., 2015).

4.1. Standard Deviation of a Ventilation Network

The standard deviation of a ventilation network is defined as the change in time of aerodynamic parameters specific for a ventilation network in relation with the aerodynamic parameters specific for the same ventilation network in standard conditions.

For determining a parameters which is applicable for any ventilation network, regardless of its' structure and complexity, there has been used the term of ventilation network in standard conditions.

The ventilation network in standard conditions represents the structure of a ventilation network evolving at a certain time, which is characterized by the fact that all active mine workings have associated the aerodynamic parameters specific for the moment of entrance into exploitation.

Aerodynamic parameters specific for the entrance into exploitation of a mine working and the ones established through the technical project. Aerodynamic parameters specific for a mine working at a certain time during exploitation air determined through flow and pressure measurements performed on site.

4.2. Establishing the Standard Deviation of a Ventilation Network

For assessing the ventilations efficiency at a certain moment is used the A_s parameter which represents its' standard deviation. The standard deviation of a ventilation network is defined by the ratio between the equivalent orifice of the ventilation network at a certain moment A and the equivalent orifice of the ventilation network in standard conditions A_0:

$$A_s = \frac{A}{A_0} \cdot 100 \qquad (2)$$

in which:

A - equivalent orifice of the ventilation network at a certain moment (m^2);

A_0 - equivalent orifice of the ventilation network in standard conditions (m^2).

Equivalent orifice of the ventilation network at a certain moment A is determined using the approximate Eq. 3:

$$A \cong \frac{1.2}{\sqrt{R}} \quad (m^2) \qquad (3)$$

Equivalent orifice in normal conditions may be calculated using the exact Eq. 4 (i.e. for two ventilation stations):

$$A = 1.2 \sqrt{\frac{Q_m^3}{Q_{s1} \quad h_{s1} \quad + \quad Q_{s2} \quad h_{s2}}} \ (m^2) \qquad (4)$$

Equivalent orifice of the ventilation network in standard conditions A_0 is determined using the approximate Eq. 5:

$$A_0 \cong \frac{1,2}{\sqrt{R_0}} \ (m^2) \qquad (5)$$

Equivalent orifice of the ventilation network in standard conditions (i.e. for two ventilation stations) may be also calculated using the exact Eq. 6:

$$A_0 = 1.2 \sqrt{\frac{Q_{0m}^3}{Q_{s01} \quad h_{s01} \quad + \quad Q_{s02} \quad h_{s02}}} \qquad (m^2) \qquad (6)$$

In these conditions, the standard deviation of the ventilation network A_S is:

$$A_s = \sqrt{\frac{R_0}{R}} \cdot 100 \quad ; A_s = \sqrt{\frac{Q_m^3 \quad (Q_{s01} \quad h_{s01} \quad + \quad Q_{s02} \quad h_{s02})}{Q_{0m}^3 \quad (Q_{s1} \quad h_{s1} \quad + \quad Q_{s2} \quad h_{s2})}} \text{ x } 100 \qquad (7)$$

4.3. Characterization of Ventilation Networks Depending on the Standard Deviation

The standard deviation of a ventilation network is a non-dimensional parameter which establishes the level of deviation from standard conditions.

In order to characterize ventilation networks in relation with the standard deviation is required the establishment of periods defining concrete states specific for the ventilation network.

Therefore, ventilation network may be split into three categories:

a) Ventilation network with optimal standard deviation characterized by $A_s > \frac{2}{A_0} \cdot 100$
b) Ventilation network with acceptable standard deviation characterized by $A_s = \frac{1}{A_0} \cdot 100 \div \frac{2}{A_0} \cdot 100$
c) Ventilation network with unacceptable standard deviation characterized by $A_s = 0 \div \frac{1}{A_0} \cdot 100$

If the ventilation network is assessed from the standard deviation point of view in different categories, then is chosen the assessment which takes into account the exactly calculated equivalent orifice.

5. LUPENI VENTILATION NETWORK SOLVING IN STANDARD CONDITIONS

For solving Lupeni ventilation network in standard conditions was used the database of VENTSIM Visual Advanced (User Guide, 2014) for solving the ventilation network in normal conditions. Figure 2 presents the 3D ventilation network of Lupeni mine unit solved for standard conditions.

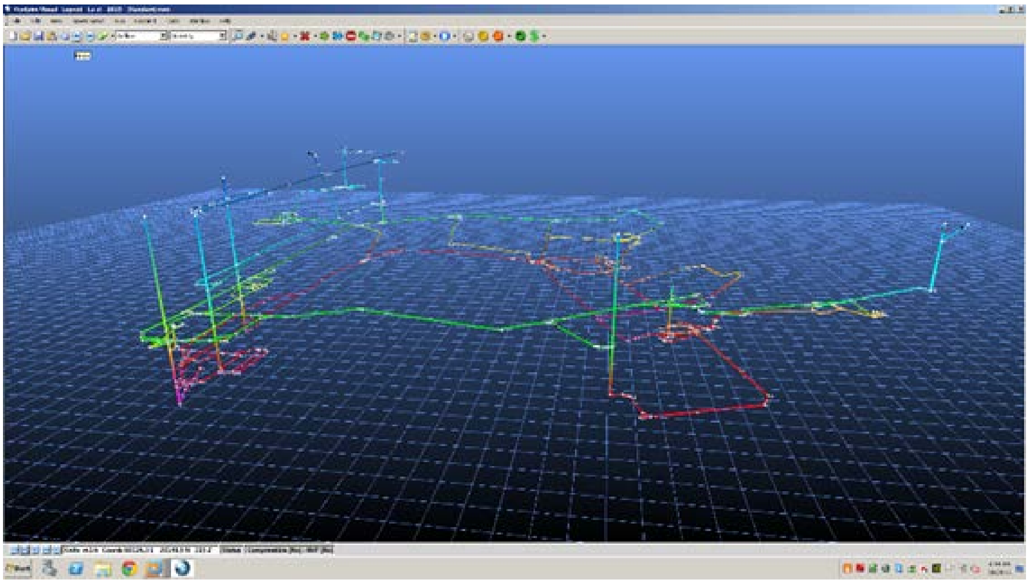

Fig. 2. 3D standard ventilation network of Lupeni mine unit

After the ventilation network's solving for standard conditions, the following results have been obtained: Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel II was 3.4 m^3/s; Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel III was 2.8 m^3/s; Air flow at the level of the longwall with undermined coal bed no. 11, seam 3, block V, was 8.0 m^3/s; Air flow at the level of the longwall no. 3, seam 3, block V, was 8.6 m^3/s; Air flow at the level of the longwall no. 2C, seam 3, block V, was 15.3 m^3/s; Air flow at mine level was 107.6 m^3/s; Air flow at the level of the main ventilation stations was 108.6 m^3/s.

6. DETERMINING THE STANDARD DEVIATION FOR LUPENI MINE UNIT VENTILATION NETWORK

For determining the standard deviation of a mine is required the knowledge of aerodynamic parameters specific for the ventilation network, respectively of operational parameters of active fans. The aerodynamic and operational parameters are required both for the ventilation network solved in normal conditions, as well as for the ventilation network brought to its' standard condition.

6.1. Standard Deviation Calculation

For calculating the standard deviation is determined the equivalent resistance of the ventilation network in normal conditions:

$$R = \frac{R_1 \quad R_2}{(R_1 + R_2 + 2\sqrt{R_1 \quad R_2})} \ (Ns^2/m^8) \tag{8}$$

Particularly for Lupeni mine unit ventilation network we have the following: R= 0.26753 (Ns^2/m^8)

The equivalent resistance of the ventilation network in standard conditions is calculated using Eq. 9:

$$R_0 = \frac{R_{01} \quad R_{02}}{(R_{01} + R_{02} + 2\sqrt{R_{01} \quad R_{02}})} \ (Ns^2/m^8) \tag{9}$$

Particularly for Lupeni mine unit ventilation network we have the following: R_0 = 0.05846 (Ns^2/m^8).

Based on previous results is determined the ventilation network's equivalent orifice in normal conditions:

$$A \cong \frac{1{,}2}{\sqrt{R}} \ (m^2); \ A \cong 2.32004 \ (m^2) \tag{10}$$

The equivalent orifice in normal conditions is exactly calculated using Eq. 11:

$$A = 1.2 \sqrt{\frac{Q_m^3}{Q_{s1} \quad h_{s1} + Q_{s2} \quad h_{s2}}} \ (m^2) \quad ; A = 1.93973 \quad (m^2) \tag{11}$$

The equivalent orifice of the ventilation network in standard conditions is calculated using the approximate Eq. 12:

$$A_0 \cong \frac{1.2}{\sqrt{R_0}} \ (m^2); \ A_0 \cong 4.96308 \ (m^2) \tag{12}$$

The equivalent orifice in standard conditions is exactly calculated using Eq. 13:

$$A_0 = 1.2 \sqrt{\frac{Q_{0m}^3}{Q_{s01} \quad h_{s01} + Q_{s02} \quad h_{s02}}} \ (m^2); \ A_0 = 3.78194 \ (m^2) \tag{13}$$

Based on the previous results is determined the ventilation network's standard deviation:

Thus, there may be determined the standard deviation based on the approximate mathematical Eq. 14:

$$A_s \cong \sqrt{\frac{R_0}{R}} \cdot 100;\ A_s \cong 46.75 \tag{14}$$

Also, by using Eq. 15 which uses the values of exactly calculated equivalent orifices for the situation of normal and standard conditions ventilation networks.

$$A_s = \frac{A}{A_0} \cdot 100 \quad \text{or } A_s = 51.29 \tag{15}$$

6.2. Ventilation Network Characterization in Relation with the Standard Deviation

In order to characterize the ventilation network in relation with the standard deviation, there are firstly calculated the ratios $\frac{1}{A_0} \times 100$ and $\frac{2}{A_0} \times 100$, using the equivalent orifice in standard conditions with approximate value:

$$\frac{1}{A_0} \times 100 = 20.149;\ \frac{2}{A_0} \times 100 = 40.297 \tag{16}$$

or by using the equivalent orifice in standard conditions with exact value:

$$\frac{1}{A_0} \times 100 = 26.44;\ \frac{2}{A_0} \times 100 = 52.883 \tag{17}$$

For the value of the standard deviation A_s = 46.75, calculated using the value of the approximate equivalent orifice, results that Lupeni mine unit ventilation network frames into category a) "Ventilation network with optimal standard deviation".

Also, for values of the standard deviation A_s = 51.29, calculated using the value of the exact equivalent orifice, results that Lupeni mine unit ventilation network frames at the upper limit of category b) "Ventilation network with acceptable standard deviation".

If the ventilation network is assessed in terms of standard deviation into different categories, then is chosen the ventilation network assessment which takes into account the exactly calculated equivalent orifice.

Therefore, the final assessment of Lupeni mine unit ventilation network in terms of standard deviation is: The ventilation network frames into category b) "Ventilation network with acceptable standard deviation".

7. CONCLUSIONS

In order to assess the efficiency of the ventilation network was inserted the A_S parameter, representing its' standard deviation.

Results obtained after solving Lupeni mine unit ventilation network in normal exploitation and in standard conditions highlight the fact that a total flow of 85.4 m^3/s respectively 108.6 m^3/s is circulated in the ventilation network, through the two main ventilation stations: Central Rising and Shaft 1 East.

The assessment of Lupeni mine unit ventilation network in terms of standard deviation highlights the fact that the ventilation network frames into category b) "Ventilation network with acceptable standard deviation".

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FANS, SPECIFIC OPERATIONAL PARAMETERS OF INDUSTRIAL VENTILATION INSTALLATIONS

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Abstract: An industrial ventilation system is started each time in a work place occur noxious, in order to maintain a safe, healthy, productive and comfortable environment in conditions of work hygiene, health and safety of workers, where this need is determined not only by the human occupation level, but also by other factors, such as production processes. For choosing a proper ventilation installation, there is needed an analysis of the workplace to be ventilated so that the chosen solution to solve the problem of noxious exhaust and to respect the comfort of the workers. In this paperwork, there are presented different types of fans used in industrial ventilation, the operational parameters, the air state parameters and the aerodynamic parameters of ventilation pipes, because they have the greatest influence on the operation of a ventilation installation.

Keywords: *industrial ventilation, parameters, fans*

1. INTRODUCTION

Designing and building an individual ventilation system should harmonize comfort requirements with the user's ventilation system management, without adversely affecting other system functions. Choosing the most suitable ventilation system for a given situation is largely the key to satisfactory operation. The situations that come into practice are, however, so numerous, complex and varied, the industrial processes in such a rapid evolution, and the need for ever greater comfort, to systematize the different situations that appear and to attach to each category the most suitable ventilation system would be both difficult and impractical.

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2. TECHNOLOGICAL AIR SYSTEMS

Industrial air technology includes measures for the indoor environment (general and local), measures to prevent hazardous emissions resulting from industrial processes from evacuation to the outside, such as transport and purification technologies, and measures to prevent or minimize the damage caused by accidents, fires or explosions. Industrial air-conditioning systems can be classified into two categories: industrial ventilation and air-processing technologies. Within this system is part of (Al. Cristea, 1968), (D. Cioclea, 2013):

- Air conditioning systems that control air and environmental quality for both human factor and process.

- General ventilation systems where some internal parameters are only partially controlled. Target levels are usually lower than those for air conditioning.

- Local ventilation systems are used for locally controlled areas. These systems are based on local capture of contaminants.

- Process ventilation systems are designed to maintain defined conditions to ensure process performance (eg, paper machine's fume cupboard).

3. FANS

Fans are rotary machines for increasing the air pressure (static pressure) transformed from the mechanical energy received on the motor shaft. The main elements of a fan are the rotor, casing and rotor system (Al. Cristea, 1968).

Following the direction of the airflow in the fans, they are classified into centrifugal or radial fans and axial fans.

Depending on the operating principle, fans may be (Fig. 1) (Al. Cristea, 1968), (I. Matei, 2000), (Băltăreţu Raul, 1980):

- axial, where the air enters directly into the fan and is centred on the axis of rotation of the engine. Due to the relatively high rotation speeds compared to centrifugal fans, the axial fans are louder;
- centrifugal, in which the air penetrates axially, makes a right angle and then moves radially outwardly under the action of centrifugal force. The rotor blades may be straight or curved front or rear relative to the direction of rotation;
- bifurcated are usually auxiliary fans that are designed so that the motors operate in fresh air while the rotor is driving vicious air;
- combined (mixed) flow are mainly centrifugal mounted in such a way that they can operate in the same way as the axial ones, the air enters the axial fan and leaves the fan at an angle that may vary from 30 ° to 90 °;

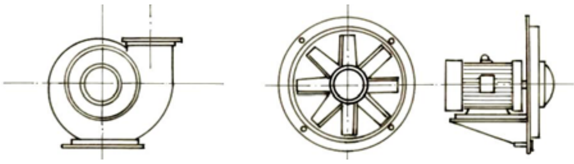

Fig. 1. Centrifugal and axial fans: a) centrifugal fan; b) axial fan

3.1. Axial fans

Axial fans owe their name to the fact that the air movement is along the fan axis. Generally, axial fans are used at high air flows and at low pressures. An axial fan consists of a tubing with a shaft or hub on which a number of blades are fixed. (William A. Burgess, 2004)

Fans with propellers are common ubiquitous air fans for homes, offices and hot work environments (Fig. 2).

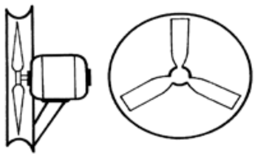

Fig. 2. Fans with propellers

Tubular fan with propellers (Fig. 3) are essentially a more complex version of propeller fans that have been modified so that they can be inserted into a duct (William A. Burgess, 2004).

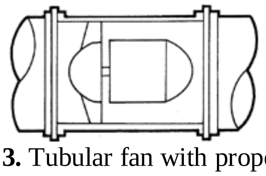

Fig. 3. Tubular fan with propeller

Vane-axial (Fig. 4) are tubular fans that have been modified by adding air-guiding blades to the engine housing behind the fan blades (William A. Burgess, 2004).

Such fans can operate at static pressures of up to 2000 Pa and are therefore suitable for use in local exhaust systems, being used as fresh air intake fans (William A. Burgess, 2004).

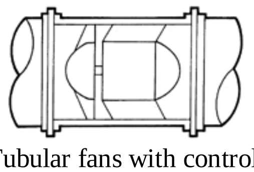

Fig. 4. Tubular fans with control blades

3.2. Centrifugal fans

Centrifugal fans use a rotor to increase the flow of air. As the air moves from the rotor hub to the blade tips, it gains kinetic energy.

A centrifugal fan works on a totally different principle than the axial ones. The centrifugal word means flowing from the centre (Fig. 5), (Al. Cristea, 1968).

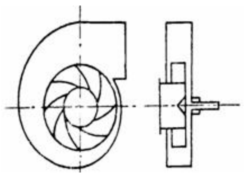

Fig. 5. Typical centrifugal fan (horizontal air suction and vertical discharge)

After the number of suction mouths, the centrifugal fans are single-aspirating and double-aspirating and, after the total developed pressure, they are classified in (Al. Cristea, 1968):

- low pressure fans (up to 100 daPa);
- medium pressure fans (up to 500 daPa;
- high pressure fans (up to 1000 daPa), above this pressure, their construction must to be modified, entering into other categories of machinery;

3.3. Bifurcated ventilators

Bifurcated ventilators are typically auxiliary fans that are designed so that the motors operate in fresh air while the rotor circulated vicious air. To do this, the fan casing is designed to allow the air to pass anywhere as the engine is encapsulated (Fig. 6) (William A. Burgess, 2004).

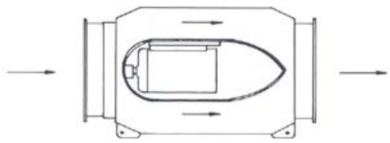

Fig. 6. Bifurcated fans

3.4. Combined flow fans (mixed)

Mixed rotation fans are hybrid fans in the sense that they are typically mainly centrifugal mounted in such a way that they can operate in the same way as the axial ones. With these fans, the air enters the axial fan and leaves the fan at an angle that may vary from 30 ° to 90 °. The flow of air through the rotor thus becomes partially centrifugal (Fig. 7) (William A. Burgess, 2004).

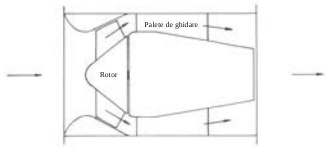

Fig. 7. Mixed air flow fan

4. FUNCTIONAL PARAMETERS OF INDUSTRIAL VENTILATION INSTALLATIONS

The functional parameters defining the performances of a fan are: airflow, pressure, speed, power and efficiency. In addition to functional parameters, it is also necessary to know the parameters of the air condition (temperature, humidity, absolute pressure, air velocity) and the aerodynamic parameters of the ventilation ducts (the geometric elements of the column, the aerodynamic resistance of the column, the unit coefficient of loss of air) as it mostly determines the operation of a ventilation system.

4.1. Functional parameters of a fan

The functional parameters of a fan are: airflow, pressure, speed, power, output, voltage (Al. Cristea, 1968), (I. Matei, R. Moraru, 2000), (Băltăretu Raul, 1980), (INCD-INSEMEX Study, 2013).

Fan flow - is the number of cubic meters of air trained in the unit of time in the suction mouth, expressed in m^3 / h.

The air flow inside a duct or the suction and discharge port of the fan is determined by the geometrical elements of the pipe (section of the pipe) and the air flow rate therein.

The formula for calculating the air flow is given by the relationship:

$$D = s \cdot v \cdot 3600 \qquad [m^3/h] \qquad (1)$$

Fan pressure - is the actual pressure produced by it and expresses the increase in fan pressure between the suction and discharge ports. The total fan pressure is equal to the sum of the total pressure measured at suction and fan discharge (dynamic pressure and static pressure).

4.1.1. The absorbed power of a fan (Pa)

The total power of a fan is the power absorbed (Pa) from the power source required to provide effective power to the fan shaft and is determined with:

$$Pa = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi \qquad (kw) \qquad (2)$$

depending on the values obtained from the measurements for the current, the electrical voltage and the power factor.

4.1.2. The useful power specific to the ventilation (Pu)

The useful power of a fan is the useful mechanical work done in the time unit for air circulation and is given by the expression:

$$P_u = (Q \times H) / 102 \text{ (kW)} \quad \text{or} \quad P_u = (Q \times H) / 1000 \text{ kW)} \tag{3}$$

where: Q - fan flow rate [m^3/s];
H - Fan depression [mm of water] or [Pa]

4.1.3. Fans speed and drive motors

The speed of an engine or fan (n_M, n_V) is the circular motion of the rotor around its axis or from a fixed point made to the point of departure and expressed in rpm.

$$\frac{n_M}{n_V} = \frac{D_V}{D_M} \tag{4}$$

where: n_M, n_V - engine and fan axle rotations (rot / min)
D_M, D_V - pulley diameters on the motor and fan shaft (m)

4.1.4. Fan yield

Fan efficiency - is the ratio between the useful power and the absorbed power received at the fan shaft, determined with:

$$\eta = (N_u / N_a) = [(Q_v P_v) / 1000\ N_a] \times 100 \quad [\%] \tag{5}$$

in which:

Qv - airflow rate developed by the fan, m^3/s;

Pv - Fan pressure, Pa, total or static to yield total or static efficiency;

Na - power absorbed at engine spindle, kW.

The rational operating range of a fan can be ensured by observing the stable operating condition ($P_v \leq 0{,}9\ P_{max}$) and by an economical operation ($\eta_v = 0{,}85\ \eta_{max}$.).

4.2. Air condition parameters

Air condition parameters include: air temperature, air humidity, absolute air pressure and air flow rate in the duct. These parameters are the most important characteristics of the ambient air, having a direct influence on human health and on the effectiveness with which they operate (Al. Cristea, 1968), (I. Matei, 2000), (Florica Băltărețu, 1987):

- **Air temperature -** is measured with an ordinary thermometer, a dry tank or electronic devices.

- **Relative humidity -** the ratio between the mass of water vapour contained in an air volume at a given temperature and the mass of the vapour required to saturate the same volume of air at the same temperature and expressed as a percentage (% RH).

- **Absolute air pressure -** Barometers are devices for measuring absolute static air pressure.

4.2.1. Air flow rate

Air velocity in pipelines is chosen according to the destination of the plant. In systems in social, cultural, administrative, commercial, sanitary, residential and similar buildings, the air velocity in pipelines is limited by noise conditions. Installations in industrial halls, which usually drive large airflows and can operate under less severe silences, are sized on the basis of higher air velocities.

In order to determine the required speeds for the transport of solid particles in pipelines, Dalla-Valle's approximate formulas can be used, namely (D. Cioclea, 2013):

- for horizontal pipelines:

$$v = 9\,\frac{\gamma_p}{\gamma_p + 16}\,d_p^{0,4} \quad \text{(m/s)} \qquad (6)$$

- for vertical pipelines carrying the particles upside down:

$$v = 20\,\frac{\gamma_p}{\gamma_p + 16}\,d_p^{0,4} \quad \text{(m/s)} \qquad (7)$$

in which:

γ_p - is the specific weight of the transported material in kg/m^3;

d_p - maximum particle size in mm.

The choice of air velocity in pipelines should always be done with discernment. First, the functional criterion has to be considered.

Also, the value of the velocity of the air flow in the column of tubes can be determined by the relation (I. Matei, 2000), (Florica Băltărețu, 1987):

$$V = \sqrt{\frac{2\,g\,h_d}{\rho}} \ \text{(m/s)} \qquad (8)$$

in which:

g - gravitational acceleration m/s^2

hd - the final mean dynamic pressure (pressure), Pa;

ρ - air density, kg /m^3

4.3. Aerodynamic parameters of the ventilation ducts

These parameters include: the section of the pipeline, the unitary aerodynamic resistance R_0 and the unit air loss coefficient K_0 (I. Matei, 2000), (Florica Băltărețu, 1987), (D. Cioclea, 2013).

4.3.1. Geometrical elements of pipelines

The shape of the industrial ventilation ducts is chosen depending on the available space, the possibility of incorporating them in the structure of the building, the airborne suspension particles. They are round or square in shape because they have the highest transport capacity (m^3/h of air) per square meter of lateral surface of the pipe. Also, the air must be run on the shortest way, with a mini-local resistor, and the pipe should be of an appropriate average length.

Measure the geometrical elements of the pipe (width, height, diameter) depending on the cross-sectional shape, calculate the free surface and their perimeter using the mathematical relations of the pipe shape.

4.3.2. Aerodynamic resistance of the ventilation columns

To determine the aerodynamic resistances specific to the R, R_0, R_C, aerodynamic columns, the Atkinson laws (Al. Cristea, 1968), (I. Matei, 2000), (Băltăreţu Raul, 1980), apply:

$$p = \alpha L \frac{P_e}{A^3} Q^2 \quad \text{[Pa]} \quad \text{or} \quad p = \frac{\alpha L P_e}{A^3} \ \text{[N s}^2\text{/m}^8 \text{ or kg/m}^7\text{]} \qquad (9)$$

where: α represents an aerodynamic friction coefficient, depending on the density of the air and expressed in density units, kg /m^3.

To determine the aerodynamic resistance of an air column, the relationship $p = RQ^2$, which is the square law of the fluid flow, applies.

The unitary aerodynamic resistance R_0, characteristic of leaky columns, is determined by the relationship:

$$R_0 = (P_1 - P_2) / Q_m^2 \quad [(\text{daPa} \times \text{s}^2/\text{m}^6)/\text{m}] \qquad (10)$$

in which:

P_1 - represents the pressure measured at a point of the column, to the fan, daPa;

P_2 - represents the pressure measured at a point in the column, to the zone of release of harmful gases, daPa;

Q_m - air flow rate in the air column, between the two measuring points, m^3/s;

L - the length of the column between the measuring points, m.

4.3.3. Unit coefficient of air loss

K_0 - represents the difference between the air flow rate developed by the fan and the air flow rate at the column air intake or clear air exhaust in the the area of the formation of noxes and expressed in m^3/s of leakage per one meter of column. Air losses mean either airflows drawn along the column or column airflow outflows along its entire path, and is determined by the relationship (I. Matei, R., 2000), (Florica Băltăretu, 1987), (D. Cioclea, 2013):

$$K_0 = \frac{3(Q_1 - Q_2)(P_1 - P_2)}{2L(P_1^{3/2} - P_2^{3/2})} \quad [m^3/s/m \text{ at the pressure } P_1 - P_2] \tag{11}$$

If at the end of the column opposite to the fan, the pressure is null, ie $P_2 = 0$, there is obtained:

$$K_0 = \frac{3(Q_1 - Q_2)}{2L\sqrt{P_1}} \quad [m^3/s/m \text{ at the pressure } P_1] \tag{12}$$

5. CONCLUSIONS

1. Technological air processing systems may be: air conditioning systems that control air and environmental quality for both human factor and process; general ventilation systems where some internal parameters are only partially controlled. These systems are based on local capture of contaminants; Process ventilation systems are designed to maintain defined conditions to ensure process performance (e.g., paper machine fume cupboards).

2. By principle of operation the fans can be axial, centrifugal, bifurcated and combined (mixed);

3. Parameters defining the performances of a fan are: air flow, pressure, speed, useful power, power absorbed, and efficiency. The air condition parameters in a pipe are the temperature, humidity, absolute pressure and air circulation speed, and the aerodynamic parameters of the ventilation ducts are: the geometric elements of the pipe, the unitary aerodynamic resistance R_0 and the unit air loss coefficient K_0;

4. The unitary aerodynamic resistance R_0 - determines the characteristic pressure loss for a given air flow rate over a given length and is obtained from measurements of pressure, temperature, absolute pressure and airflow velocity measurements using calculation relations;

5. The unit air loss coefficient K_0 is obtained from measurements of pressure, temperature, absolute pressure and air flow velocity and represents the difference between the air flow rate developed by the fan and the air flow rate at the suction nozzle air in the column or clean air discharge in the area of the formation of emissions and expressed in m^3/s of leakage air per one meter of column.

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RESEARCH ON THE IDENTIFICATION OF THE DANGERS OF DUST AND WATER ENTERING EQUIPMENT FOR POTENTIALLY EXPLOSIVE ATMOSPHERES

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Abstract: In order to be used safely, all electrical or non-electrical equipment operating in areas with potentially explosive atmospheres should be provided with enclosures that provide a certain degree of IP protection (International Code). According to the general standard SR EN 60079-0 in hazardous areas Ex it is necessary that an electrical / non-electrical equipment, in addition to the specific type of protection, must provide at least a standard degree of protection IP XX, the test procedures being in accordance with the requirements of SR EN 60529 and in the case of rotating electric machines according to SR EN 60034-5. The normal degree of protection is protection against access to hazardous parts inside the enclosure and protection against penetration of solid bodies and protection against water penetration inside the equipment. Tests for the determination of the first characteristic number - protection against penetration of solid bodies are particularly important for equipment intended for use in hazardous areas of explosive atmospheres generated by combustible dust as this protection is also a requirement for explosion protection. Within the ENExEMEIP laboratory of INCD INSEMEX, laboratory tests have been developed to verify the first characteristic figure by building a high performance dusting chamber, according to the method standardized of European standard, and purchasing a stand for checking the protection against falling water in the form of rain and against water projections, which determines the second characteristic number 3 and 4.

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Keywords: *potentially explosive atmospheres; normal protection degree; combustible dust.*

1. GENERALITY

Many types of dust that are generated, processed, handled and stored, are combustible. When ignited they can burn rapidly and with considerable explosive force if mixed with air in the appropriate proportions. It is often necessary to use electrical apparatus in locations where such combustible materials are present, and suitable precautions must therefore be taken to ensure that all such apparatus is adequately protected so as to reduce the likelihood of ignition of the external explosive atmosphere. In electrical apparatus, potential ignition sources include electrical arcs and sparks, hot surfaces and frictional sparks.

Areas where dust, flyings and fibers in air occur in dangerous quantities are classified as hazardous and are divided into three zones according to the level of risk.

Generally, electrical safety is ensured by the implementation of one of two considerations, i.e. that electrical apparatus be located where reasonably practicable outside hazardous areas, and that electrical apparatus be designed, installed and maintained in accordance with measures recommended for the area in which the apparatus is located. Combustible dust can be ignited by electrical apparatus in several ways:

- by surfaces of the apparatus that are above the minimum ignition temperature of the dust concerned. The temperature at which a type of dust ignites is a function of the properties of the dust, whether the dust is in a cloud or layer, the thickness of the layer and the geometry of the heat source;
- by arcing or sparking of electrical parts such as switches, contacts, commutators, brushes, or the like;
- by discharge of an accumulated electrostatic charge;
- by radiated energy (e.g. electromagnetic radiation);
- by mechanical sparking or frictional sparking associated with the apparatus.

In order to avoid ignition hazards it is necessary that:

- the temperature of surfaces on which dust can be deposited, or which would be in contact with a dust cloud, is kept below the temperature limitation specified.
- any electrical sparking parts, or parts having a temperature above the temperature limit specified.
- are contained in an enclosure which adequately prevents the ingress of dust, or
- the energy of electrical circuits is limited so as to avoid arcs, sparks or temperatures capable of igniting combustible dust;
- any other ignition sources are avoided.

2. NORMAL DEGREE OF PROTECTION PROVIDED BY THE ENCLOSURES OF THE EQUIPMENT

When choosing, designing and installing electrical equipment intended for use in explosive atmospheres, besides the protective measures required (choice of anti-explosion protection, temperature class and explosion group of liquids, explosives, mists and / or dust suspensions in air or in the form of a layer), electrical installations must be protected by enclosures to ensure:

- Protect people from access to dangerous parts inside the carcass (parts moving or under voltage);
- Protection of equipment inside the enclosure against the penetration of foreign solids;
- Protection of equipment inside the enclosure against harmful effects due to water penetration.

The significance of each characteristic figure is given in Tables 1, 2 and 3 (SR EN 60529:1995 + SR EN 60529:1995/A1:2003).

Table 1. The significance of first characteristic figure

		NAME	EXPLANATIONS
FIRST CHARACTERISTICS	0	Unprotected	• Touching the parts moving or under voltage inside the enclosure is not obstructed; • The penetration of foreign solids is not hindered
	1	Protected against penetration of foreign solids larger than 50 mm	• Accidental or intentional touching of internal parts under voltage or in motion, with a large surface of the human body, for example the hand, is not possible. Voluntary touch is possible; • Penetration of foreign solid bodies up to 50 mm in diameter is prevented
	2	Protected against penetration of foreign solids 12 mm or larger	• Touching or wishing with finger or analog objects whose length does not exceed 80 mm, internal parts under voltage or moving is prevented; • Penetration of foreign solid bodies with a diameter of 12 mm or more is prevented
	3	Protected against penetration of foreign solid bodies of 2.5 mm or larger	• Touching with tools, wires, etc. with a diameter or thickness of more than 2.5 mm, of the internal parts under voltage or in motion is prevented; • Penetration of foreign solid bodies with a diameter equal to or greater than 2.5 mm is prevented

	4	Protected against penetration of solid bodies foreign than 1 mm or larger	• Tapping with wires or bands over 1 mm thick, internal parts under voltage or moving is prevented; • Penetration of foreign solid bodies with a diameter equal to or greater than 1 mm is prevented
	5	Protected partially against dust penetration	• Touching in any way the internal parts under voltage or in motion is prevented; • The penetration of the dust is not completely obstructed, it can penetrate only to the extent that it does not impede the proper functioning of the electrotechnical product
	6	Protected completely against dust penetration	• Touching in any way the internal parts under voltage or in motion is prevented; • Dust penetration is completely obstructed

Table 2. The significance of second characteristic figure

		NAME	EXPLANATIONS
THE SECOND CHARACTERISTIC	0	Unprotected	• Water penetration is not obstructed
	1	Protected against vertical drops of water	• Water droplets falling vertically should have no harmful effects
	2	Protected against drops of water falling below an angle of max. 15 ° to the vertical	• Drops of water falling below an angle of max. 15 ° to the vertical should not have harmful effects, ie drops of rain falling vertically do not damage the product inclined at an angle of max. 15 ° to the vertical
	3	Protected against water falling as rain	• Water falling as rain, at an angle of max. 60 ° to the vertical must not have harmful effects
	4	Protected against splashing with water	• Water sent from all directions on the housing must be free of harmful effects
	5	Protected against water jets	• Water sent with a hose in all directions on the housing must be free of harmful effects
	6	Protected against shipboard conditions	• Water from strong waves or jets must not penetrate the carcass in harmful quantities
	7	Protected against the effects of immersion in water	• The penetration of harmful water into the enclosure completely immersed in water at a given pressure and time must not be possible (checked according to Table 4, figure 7)
	8	Protected against prolonged immersion in water	• The product resists prolonged immersion in water under conditions specified by the manufacturer
	9	Protected against high pressure and high water jets	• High pressure and high-temperature water from any direction on the housing must be free of harmful effects

Enclosures of electrical or non-electrical equipment, whether used in normal environments or potentially explosive atmospheres, must provide a certain degree of IP protection.

In accordance with general standards that set out the basic methods and requirements for the design, construction, testing and marking of electrical and non-electrical equipment for use in potentially explosive atmospheres with gas, vapor, fog and combustible dust: SR EN 60079-0 and SR EN ISO 80079-36 it is necessary for the equipment to be provided with a housing with a specific IP protection degree for a certain type of protection. The specific test procedures are in accordance with the requirements of SR EN 60529-1995 / A1-2003 and SR EN 60529-1995 / A2-2015, and for rotary electric machines according to SR EN 60034-5.

If a characteristic number is not required, it should be replaced by the letter "X" (or "XX" if both digits are omitted), eg: IP6X; IPX7; IPX6 / IPX8).

In practice, the following degrees of protection can be achieved, shown in Table 3.

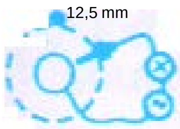
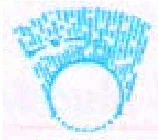
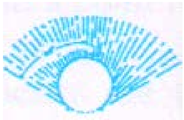
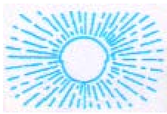
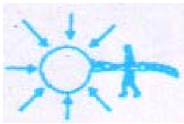
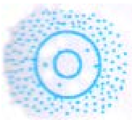
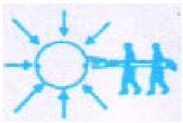
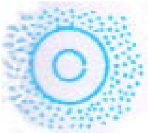
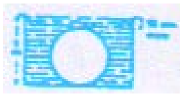
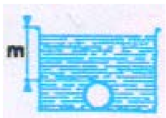
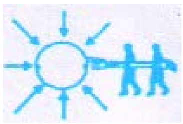
Table 3. Degrees of protection

CODE	The first characteristic figure (solid bodies)	The second characteristic figure (water)									
		0	1	2	3	4	5	6	7	8	9
IP	0	IP00	-	-	-	-	-	-	-	-	-
	1	IP10	IP11	IP12	-	-	-	-	-	-	-
	2	IP20	IP21	IP22	IP23	-	-	-	-	-	-
	3	IP30	IP31	IP32	IP33	IP34	-	-	-	-	-
	4	IP40	IP41	IP42	IP43	IP44	-	-	-	-	-
	5	IP50	-	-	-	IP54	IP55	-	-	-	-
	6	IP60	-	-	-	-	IP65	IP66	IP67	IP68	IP69

The synthesis of the tests for determining the IP code digits is shown in Table 4 (SR EN 60529:1995/A2:2015 + SR EN 60529:1995/AC:2017).

Table 4. The synthesis of the tests for determining the IP code digits

IP	Test	Description	IP	Test	Description
0		Unprotected	**0**		unprotected
1		protected against foreign solids with a diameter of 50 mm and above (protected from hand-held access to	**1** 		protected against drops of water falling vertically

		dangerous parts)				
2		protected against foreign solids with a diameter of 12 mm or more (protected against finger contact at dangerous parts)	2			protected against vertical droplets of water that can be rotated at 15 °
3		protected against solid foreign bodies with a diameter of 2.5 mm and higher (fine tools, wires)	3			protected against spraying water at an angle of up to 60 ° to the vertical
4		protected against solid foreign bodies with a diameter of 1 mm and higher (fine tools, wires)	4			protected against sprayed water on all sides
			5			protected against jets of water from all sides
5 		protected against dust (against hazardous deposits)	6			heavy water jet, equivalent to sea waves during storm
6 		Dust-tight	7			protected against immersion in water
			8			protected during permanent immersion in water (1000 mm)
			9			protected against strong water jets (high pressure and high temperature)

3. IMPROVEMENT METHODS AND TECHNICAL TESTS FOR TECHNICAL EQUIPMENT

In the framework of the PN - ELTOX project, in the ENExEMEIP Laboratory, the principle diagrams were developed and the tender dossiers for the purchase of two test stands were elaborated:

- A dust chamber designed for large-scale equipment to determine partial or total dust protection (IP 5X and IP 6X);
- An automated stand for water spray testing (IP X3 and IP X4).

According to the basic principles presented in Fig. 1 in which the dust circulation pump can be replaced by other means to keep the suspension of talcum powder in a closed test chamber. The talc powder used must be able to pass through a square mesh fabric at which the nominal yarn diameter is 50 µm and the free space between threads of 75 µm. The talc powder used is 2 kg per cubic meter of the test chamber. The talc should not be used in more than 20 attempts.

Depending on the category established by the manufacturer, the dust-proofing test inside the equipment is carried out using the vacuum pump (for category 1 carcases) and without the vacuum pump (for category 2 carcases).

According to SR EN 60529-1995 / A1-2003, the electrical equipment casings are divided into two categories:

- Category 1: enclosures where the normal operating cycle of the equipment causes reductions in internal pressure relative to ambient air due, for example, to the effects of thermal cycles.
- Category 2: housings in which there is no pressure difference with respect to ambient air.

In general, machinery intended for use in potentially explosive atmospheres of fuel-dust atmospheres must have a standard IP 5X or IP 6X protection rating and enclosures when testing for the first characteristic figure: -5- protection partial dustproofing, ie total protection against dust penetration, are considered to be of category 1, which in the normal operating cycle are heated and therefore the test is carried out in the dust chamber using the vacuum pump.

The pump connection must be made through a hole specially designed for this test. Without a different specification from the specific product standard, this hole must be in the vicinity of vulnerable parts. If there are other holes (eg other head inlets or outlet holes), they should be treated as normal.

The purpose of the test is to pass through the housing, with a depression, a volume of air equal to 80 times the volume of the test case without exceeding a 60-hour extraction rate of the carcass volume. Under no circumstances should the depression be greater than 2 kPa (20 mbar) in the manometer shown in Figure 2. If the extraction rate is 40 to 60 volumes per hour, the test takes 2 hours.

For testing the characteristic digit IP 5X or IP 6X for large-dimension equipment, use the dust chamber shown in Fig. 1.

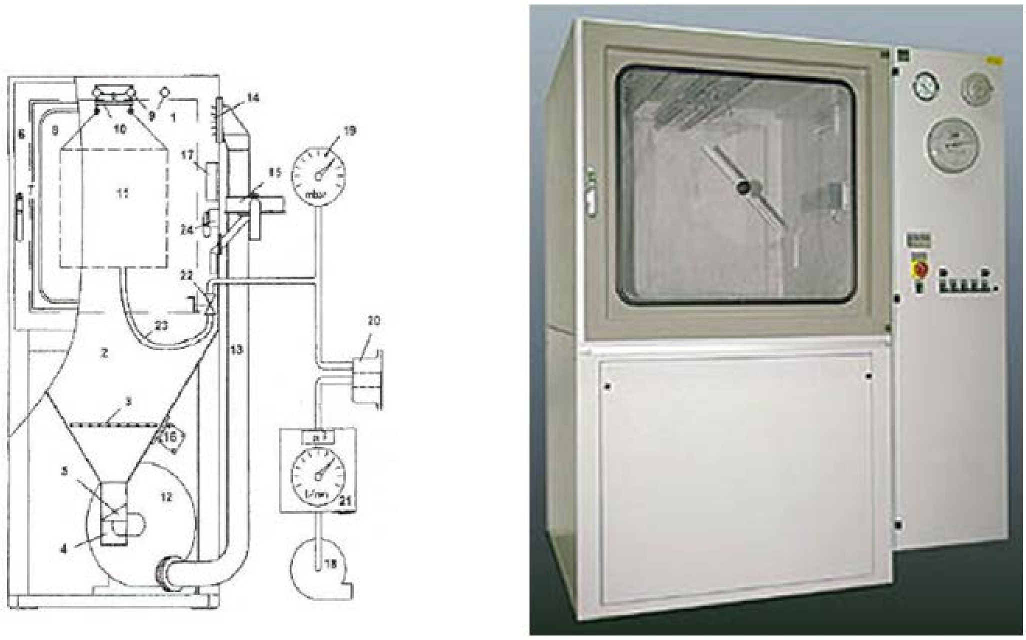


Fig. 1. Dust test Chamber – principal scheme

Enclosures with the degree of protection IP 5X “Dust protected” do not have to prevent ingrees of dust totally. However, dust should not penetrate in an amount sufficient to interfere with the satisfactory operation of the equipment enclosed or to impair safety. In the case of enclosures with degree of protection IP6X “Dust tight” it is necessary to prove that no dust can penetrate into the inside of the enclosure. The test are carried out by means of a dust chamber with a sealed test cabinet, in which talcum powder is kept in suspension by means of an air stream. The talcum powder must be prepared in such a manner that it will pass through a sieve with a mesh size of 0,075 mm. The quantity of talcum given in the regulation is 2 kg per cubic of test cabinet volume.

Attempts to protect against water penetration, indicated by the second characteristic figure, are performed with fresh water. During the tests for IP X1 to IP X6, the water temperature must not differ by more than 5 K from that of the product under test. In the case of tests for determining the IP X9, the equipment protected against strong water jets is subjected to high pressure and high temperature (upon agreement between the beneficiary and the manufacturer).

During the test, moisture inside the housing may partially condense. The condensing water that is deposited should not be considered as the penetration of the outside water.

To test the characteristic figure IP X3 or IP X4 in the case of small size equipment, an automated oscillating tube stand is used, as shown in Fig. 2.

The stand has been designed to provide: an adjustable height of 500 to 1250 mm, the possibility of installing an oscillating spring with a radius between 200 ... 1800 mm; the adjustable speed of the oscillating spring (adjustable); possibility of limiting oscillation angle (oscillations of almost 3600, 1800 on both sides of the vertical); adjustable test duration between 1 and 60 min; adjustable pressure, flow adjustment 30 ... 300 l / h; rotary sample placement with automatic oscillating motion and oscillating speed adjustment.

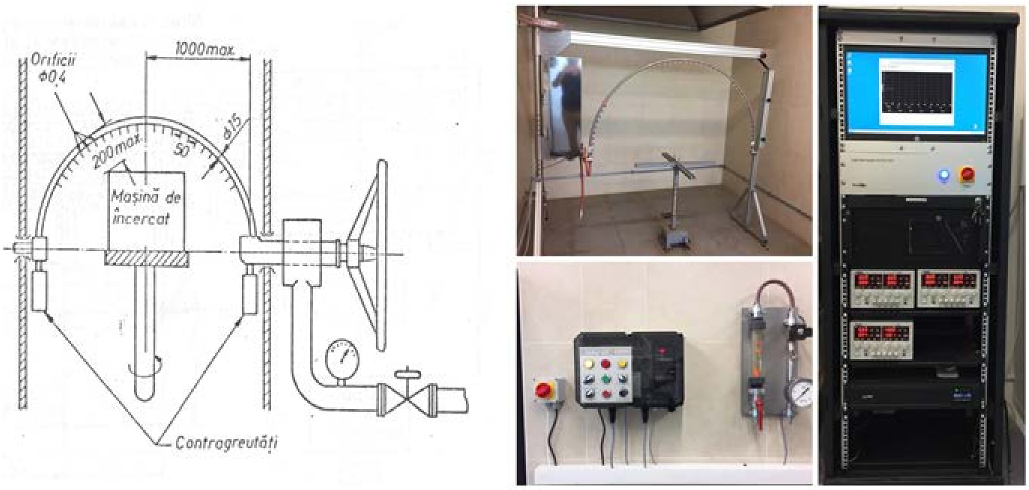


Fig. 2. Apparatus for checking the protection against falling rainwater and water projections; The second characteristic number 3 and 4 (oscillating tube)

5. CONCLUSIONS

Dust and water penetration tests inside electrical and non-electrical equipment, ie the determination of the first characteristic number IP 5X and IP 6X, or the determination of the second characteristic digit IP X3 and IP X4 of the normal protection degree with the stands The above test is particularly important for assessing the compliance of the equipment with the requirements of the harmonized European standards and the explosion protection requirements of the ATEX Directive, taken over in the Romanian legislation by GD 245/2016.

In order to perform these tests, the ENExEMEIP laboratory at INCD-INSEMEX Petroşani designed the technological schemes and elaborated the specifications for the purchase of a large-scale powder testing chamber and an automated water test stand in the form of rain. The stands meet the requirements of SR EN 17025, these tests may be included in the accredited testing field within the GLI laboratory.

By providing these stands, the test conditions are met to meet the demand of various manufacturers / manufacturers, importers, distributors or users for verification / certification of electrical and non-electrical equipment intended for use in potentially explosive atmospheres.

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RESEARCHES ON THE MACROELEMENTS CONTENT FROM JIU VALLEY COAL ASH

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Abstract: Worldwide, there is an increasingly acute crisis of raw materials coming from conventional resources. A way to confute this crisis is the exploitation of waste from different industries, their processing becoming competitive in the conditions of increasing costs of extracting some useful minerals. This paper aims to establish the chemical composition (macro elements) of raw coal ashes from the Jiu Valley from several mining units and to establish the chemical composition of special products from the Jiu Valley Preparation Plant in order to make an optimal decision in case of possible capitalization. From research carried out so far on raw coal ashes and special products in Jiu Valley, it has been found that there is a concentration above the average of European Union countries of metal oxides present in the coal ashes. Large amounts of ashes, exploitation efficiency and waste recycling tendency considerably reduce the technical and economic difficulties of extraction from non-bauxitic raw materials. Thus, the existence and composition of these macro elements was studied using the process of dissolving alumina in HNO3 in a quantity less than the stoichiometric value, when $Al(NO_3)_3 \cdot 9H_2O$ is formed, because the iron remains insoluble in the solution afterwards being extracted from moist and dried concentrates in soft or strong fields.

Keywords: *ash; coal; environment, macroelements*

1. INTRODUCTION

In the last three decades, the dynamics of global coal production has regressed under the influence and competition of other sources of primary energy, respectively oil and natural gas. Very economic advantageous exploitation conditions of hydrocarbon

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reservoirs, and in particular those in economically weak countries, has weighted the world balance of primary energy carriers against coal.

Typically, raw coal (as extracted from deposit) does not fully correspond to quality of various uses or technological processes. In order to bring it into the state demanded by consumers and to be used in the most economical way, coal is subjected to physical and physical-chemical processing operations, called preparation operations.

Coal preparation comprises a complex of mechanical operations (grading, grinding, concentrating, draining, etc.) to which raw coal is subjected in order to improve its quality and to adapt it to different processes where it is to be used or recovered. As a result of coal preparation process, a special product is produced in which the structure and chemical composition of coal is not changed.

Ash represents the inorganic mass of coal formed by oxidation at 850^oC. A series of elements known as minor elements or trace elements, in quantities between 1 ppm and 1% (Au, Ag, Pt, Co, Ga, In, Mo, Ni, Sn, V, Cu, Pb, Zn, Cd, etc.) and elements known as major elements or macroelements in quantities of more than 1% by weight of ash (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Na_2O, K_2O) are present in coal ash (Simion, 2014).

Coal ashes from thermoelectric plants, because of their content in various metallic oxides, are considered as new sources of raw materials. From research carried out on ash recovery, the question was put to use ashes from energetic complexes (CTE) by first extracting metal oxides (Fe_2O_3, Al_2O_3) usable in metallurgical industry followed by the use of by-products resulted for obtaining products (Ghiță et al., 1973), (Simion, 2014).

2. CONTENT OF MACROELEMENTS IN COAL ASHES

Chemical composition of ashes is particularly complex, the content and oxidic nature varying widely, depending on the genesis of coal (Petrescu et al., 1987). From mineralogical observations performed on coal-based minerals, specialists noted that they are made up of 95% loamy minerals and the rest of 5% of associated minerals are: pyrite, marcasite, dolomite, siderite, calcite, sodium and potassium halides, quartz, feldspar, magnetite, topaz, tourmaline, hematite, etc. (Petrescu et al., 1987).

In some countries, such as Poland and France, there are industrial installations for extracting metallic oxides from coal ash. In Romania, because there are no such installations, there is a need to compare ash composition in some European countries (Table 1) with ash composition in our country to check tailings quality.

Table 1. Coal ash composition in some European countries and U S.A.

Country	Composition %						
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O+K_2O
Great Britain (L)	41.4-50.7	28.6-29.9	6.4-13.3	1.7-3.7	1.4-2.9	0.6-1.8	2.0-6.1
Austria (L)	45.0-53.0	19.0-24.0	6.0-9.0	10.0-13.0	2.0-3.0	-	-
France (H)	47.0-53.0	28.0-35.0	3.6-11.5	13.4	1.4-2.5	0.1-0.9	0.9-7.3
Germany (L)	28.0-68.0	3.2-11.4	2.3-6.5	16.3-24.9	0.5-2.6	5.8-16.3	-
Greece (L)	33.0	15.5	6.0	33.0	2.0	6.0	3.0
Poland (H)	43.0-57.0	18.0-28.0	7.5-16.0	4.0-10.0	1.0-5.5	0.5-3.3	1.0-3.0
Spain (L)	36.4-51.4	11.6-34.8	7.6-27.9	0.9-11.3	0.9-2.9	0.3-3.4	0.1-3.3
U.S.A. (L)	34.0-38.0	17.3-31.0	6.0-26.0	1.0-10.0	0.5-2.0	0.2-4.0	1.5-2.0
Romania							
Pit coal (H)	38.0-51.0	23.0-32.0	7.0-18.0	1.0-6.0	0.9-3.0	0.9-3.0	1.0-3.0
Lignite (L)	35.0-54.0	11.0-25.0	7.0-23.0	3.0-28.0	1.0-4.0	0.2-15.0	1.0-4.0

Table 1 shows that in countries such as United Kingdom, Austria, France, Germany, Poland, Spain and Romania, the coal sterile is of aluminous-silicone type and only in Greece and USA the coal sterile is of calcic type.

In comparison, table 2 shows our research on the chemical composition of coal ash oxides from Jiu Valley, on mining operations, composition measured in the chemistry laboratory (Simion, 2014).

Table 2. Chemical composition of coal ash oxides from Jiu Valley

No.	Mine	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	TiO_2 (%)	CaO (%)	MgO (%)	SO_3 (%)	Na_2O (%)	K_2O (%)
1	Lonea	49.43	10.25	23.23	0.57	7.48	2.29	2.59	2.42	0.87
2	Petrila	52.29	10.51	18.96	0.78	6.60	2.69	2.35	2.97	0.73
3	Livezeni	53.26	8.31	25.69	1.04	4.44	2.20	2.30	2.10	0.53
4	Vulcan	53.69	9.78	20.5	0.71	7.48	1.35	2.65	2.78	0.75
5	Paroşeni	51.69	7.75	19.29	0.92	7.71	1.35	3.39	2.98	0.84
6	Lupeni	53.91	8.31	25.69	0.83	4.44	2.02	2.24	1.67	0.4
7	Bărbăteni	49.81	8.05	23.70	0.83	6.78	1.34	2.34	2.76	0.93
8	Uricani	52.78	12.84	17.20	0.82	5.14	1.85	2.77	2.93	0.87

The diagram of the macroelements distribution in these ashes is shown in Fig. 1.

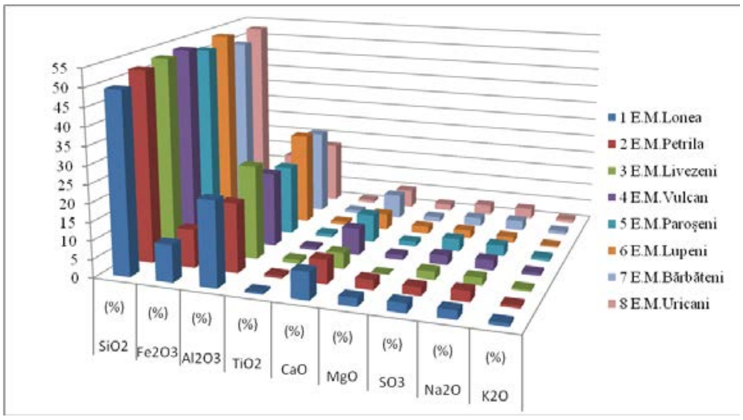

Fig. 1. Diagram of the macroelements distribution

The analysis of macroelements content in Jiu Valley coal ashes, shows that the SiO_2 content is high, classifying the coal ash into a high abrasive class, complicating the extraction process and increasing the production cost of metals obtained, but the content of useful metals and other elements that can be extracted tilts the balance in favour of ashes exploitation, to capitalize the waste resulting from oxidation.

Depending on the chemical composition of ashes, the recovery manner and technology are chosen and the chemical composition of coals actuates its behaviour in the combustion process in the furnaces of steam boilers. Thus, a high content of alkanes acts as a fusing agent, leading to slagging of ashes (Ionescu and Moldovan, 2005). Ashes containing iron oxides are more fusible than those containing aluminium oxide and silicon dioxide. A high content of silicon dioxide may indicate the presence of a significant amount of free quartz in the tailings, which generates a high abrasiveness of ash (Ghiță et al., 1973).

Higher content of sulphur trioxide in the ash composition can lead to corrosion of the boiler, accompanied by pollution of the atmosphere with sulphur oxides, harmful to flora and fauna. Knowledge of the composition of inorganic mass of coals is particularly important, not only in the case of its use for energy, but also in the case of metallurgical coal, which must have an as low as possible ash content, as it runs into coke (Moldovan et al, 2003; Moldovan and Ionescu, 2006).

3. CONTENT OF MACROELEMENTS IN SPECIAL PRODUCTS ASHES

In order to establish the chemical composition of ashes, coal was extracted from 4 mining coal mines, coal subjected to the preparation process at Coroiești Coal Preparation Plant. The methods of analysis used are in line with current standards for determining the chemical composition of ash, applicable both in industrial processes and in laboratory (STAS 10274/4-90; STAS 10274/5-75; STAS 10274/5-7).

The ash used in our case is the result of burning special coals in laboratory. The chemical analyses were carried out on three parallel samples, resulting in a final arithmetic mean of results that matched the corresponding values for maximum admissible differences for each determination method (STAS 10274/4-90; STAS 10274/5-75; STAS 10274/6-88).

The chemical composition of the special coal ash resulted from Coroieşti Preparation Plant is shown in Table 3.

Table 3. Chemical composition of the special coal ash resulted from Coroeşti Preparation Plant

No.	Preparation plant	Oxides (%)								
		SiO_2	Fe_2O_3	Al_2O_3	TiO_2	CaO	MgO	SO_3	Na_2O	K_2O
1.	Petrila	39,89	15,60	25,81	1,33	6,72	1,00	5,93	2,01	0,72
2.	Livezeni	39,06	13,51	27,56	1,57	3,50	2,02	4,19	6,52	0,61
3.	Vulcan	38,99	18,45	24,16	1,25	7,71	1,26	4,63	2,06	0,73
4.	Lupeni	35,67	13,61	29,25	0,92	6,60	2,18	4,66	5,46	0,85

The diagram of macroelements distribution in the special product ash from Jiu Valley Preparation Plants is shown in Figure 2.

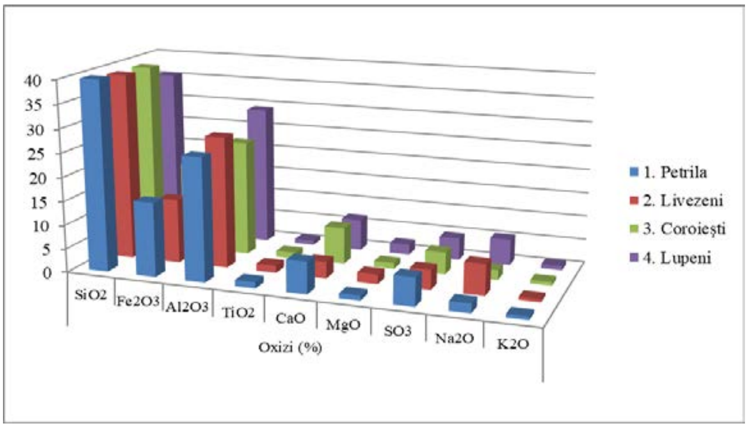

Fig. 2. Macroelements distribution in special product’s ashes

Compared to the previous situation, for ash obtained by oxidation of special coals resulting from the preparation process, the metal oxide content has improved, for alumina by up to 52% and for iron oxides by up to 62%.

The distribution of macroelements in the special product ash from Coroieşti Preparation Plant (fig. 2) shows that the useful elements replace the silicon dioxide content, which reduces cost of maintenance for combustion boilers and capitalizes the recovery cost of metallic oxides from coal ashes.

Coal preparation doesn’t have only positive effects, as sulphur trioxide (SO_3) content of the coal mass doubles, leading to a much higher level of sulphur oxides emitted into the atmosphere, requiring a gas desulphurisation plant or a modernization of the existing one.

Sulphur trioxide also creates problems in ash dumps or tailings ponds because it reacts very easily with meteoric water forming acidic hydrogen ions and mineral acidity on its path that even in case of pollution, natural receptors become unusable for domestic consumption, riverbeds are covered with precipitate that contaminates the water source and inhibits or eliminates a variety of aquatic organisms, causing severe imbalances in the food chain (Lazar and Dumitrescu, 2006). By extracting these elements from ashes, these impacts can be minimized and we will have an excess of raw material, a much less polluted area with natural landscapes, with no opportunistic species capable of inhibiting the ecosystem restoration capacity (Lazar and Dumitrescu, 2006).

After the extracting these metals, coal ash could be used as: filling material in various road works, raw material in cement production, raw material in clinker blocks production, improvement products in agriculture, anti-skid, fire and frost high resistance material etc.

Onward, we suggest a few technologies for the extraction of iron oxides and alumina from coal ashes.

4. EXTRACTION OF IRON OXIDES AND ALUMINA FROM COAL ASHES

The natural reserves of non-aluminous materials of alumina-silicate type (kaolin, clays, etc.), as well as ashes from C.T.E. regardless of the type of coal, suitable for alumina production, can be considered as inexhaustible. This view is all the more rational as global coal-based energy will record an average growth rate of 2.3% per year by 2020, less than the projected 2.6% increase, but also a real increase of 3.4% per year between 2007 and 2012, according to International Energy Agency (IEA) estimates (International Energy Agency, 2018). Experts approximate that Romania has coal, especially coal and lignite, for another 250 years (International Energy Agency, 2018).

Literature in the filed (Matjie et al., 2005), recommends the use of two different technologies for the production of alumina from non-aluminous raw materials, depending on the removal of iron from nitrate solutions, namely:

- dissolving in HNO_3 below the stoichiometric value, when $Al(NO_3)3\ 9H_2O$ is formed in contact with which the iron remains insoluble (Matjie et al., 2005);
- dissolving in HNO_3 over the stoichiometric value, when $Al(NO_3)3 \cdot 9H_2O$ is formed and the iron passes into a solution where it is subsequently removed (Matjie et al., 2005);

In order to obtain Al_2O_3 from the Jiu Valley coal ash by treatment with HNO_3, dissolution in HNO_3 below the stoichiometric value was used, $Al(NO_3)3 \cdot 9H_2O$ was formed, which in contact with the iron remained insoluble (fig.3) (Matjie et al., 2005) and for laboratory alumina production ash from Paroșeni thermal plant was used.

Optimal conditions for the leaching phase, reflected by an efficient output of alumina extraction and iron separation are:

- HNO_3 concentration = 40%;
- HNO_3/Al_2O_3 ratio = 0,9;
- Leaching temeperatur: 220^{0}C
- Leaching time: 2 hours

After filtration of the pulp to separate soluble aluminates from insoluble iron compounds Fe_2O_3, $Fe(OH)_3$, the resulting solution was evaporated and crystallized. After leaching and sedimentation, water was liberated at 120° C, while increasing the concentration of Al_2O_3 in solution. It was then treated with a 5% HNO_3 solution at 100^{0}C and exposed to crystallization. The aluminium oxide was crystallized as $Al(NO_3)3 \cdot 9H_2O$ and the next step consisted of breakdown of this compound into Al_2O_3 and HNO_3 according to the reactions:

$$2[Al(NO_3)_3 \cdot 9H_2O] \longrightarrow Al_2O_3 + 3N_2O_5 + 18H_2O$$
$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

In order to make the process more profitable, the issue of nitrate solution deferrization has been raised. The Fe_2O_3 content of the solution after leaching was 0.3g/l (0.4% Fe_2O_3) and 0.3% $Al(NO_3)3 \cdot 9H_2O$. The solution obtained from the leaching process was improved by red-sludge treatment from the extraction of alumina from bauxite, resulting in an enriched preconcentrate.

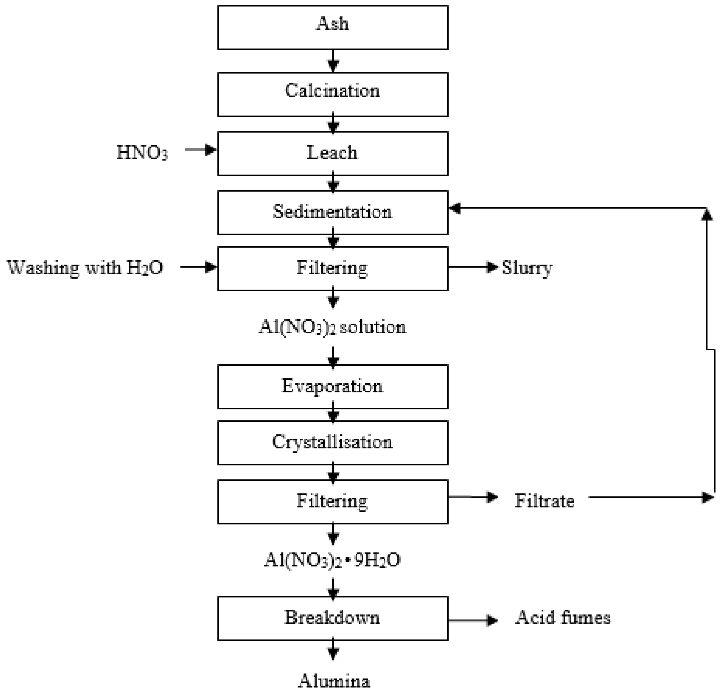

Fig. 3. Flow diagram of alumina production process by treatment with HNO_3 (Matjie et al., 2005)

Concentrations of metallic oxides present in the preconcentrate do not fall within the limit of industrial phase exploitation, and in order to move to the industrial phase two more problems needed to be solved:

- deferrization of aluminium oxide to the limit required by the norms for obtaining aluminium for electrolysis;
- increasing the recovery rate of nitrogen oxides, respectively nitric acid.

Obtaining iron oxide concentrates represents a major concern at the present stage for the complex and integral use of ashes from C.T.E. In order to obtain iron oxide concentrates from the ashes, especially methods based on the principle of magnetic separation were examined (Friedeberg, 1995). The chemical composition of ashes has shown the presence of magnetised oxides (magnetite, hematite) and compounds of manganese, calcium, magnesium, which improve the quality of iron concentrates (Friedeberg, 1995). For iron and steel metallurgy, the absence of copper, silver, arsenic, sulphur, etc. from the ashes represents an advantage because these elements belong to non-ferrous metallurgy and make it difficult to extract iron oxides (Lazar and Dumitrescu, 2006).

The separation of iron oxides from ashes has a double importance and necessity:

- attaining a new source of ferrous metal concentrates usable in steel industry;
- deferrization of ashes from C.T.E. for their use in alumina production.

Magnetite type Iron minerals are of interest for the purposes pursued. Magnetite and hematite have been identified in both the free grains as well as punctiform impregnated in the quartz and silicate masses. The most commonly used methods for obtaining concentrates refer to wet separation in weak magnetic fields and dry separation in strong magnetic fields. Concentration through flotation has an increased output for iron ores or ashes of weak magnetic components (Friedeberg, 1995; Negoiu, 1970).

The technology, consisting of weak field magnetic preconcentration, followed by grinding the preconcentrate to a fineness of less than 0.2 mm followed by a new weak field magnetic separation was verified on a pilot scale.

The preconcentrate obtained by applying a magnetic field of 11900 A / m intensity has the composition of shown in Table 4.

Table 4. Composition of preconcentrate obtained by applying a magnetic field of 11900 A / m intensity

Fe (%)	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	Mn (%)
35	25.2	10.7	2.0	0.31

5. CONCLUSIONS

Centralized data shows significant variations in the chemical composition of ash according its origin. As with coal ashes in other countries, there is a higher content of SiO_2, Al_2O_3 and Fe_2O_3 and lower in other elements (TiO_2, CaO, MgO, SO_3, Na_2O, K_2O). Ashes also have a high SO_3 content, which indicates that a reduction in the sulphur content of their composition is required. With the extraction of iron and aluminium oxides, a magnetic field preconcentration has been obtained which reveals that the reuse of a large amount of ash can alleviate or solve environmental problems. Moreover, besides solving environmental problems, the use of ash is a way to save natural resources and energy.

ACKNOWLEDGEMENTS

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STAS 10274/4-90 Ash analysis. Measurement of iron.

STAS 10274/5-75 Ash analysis. Measurement of aluminum.

STAS 10274/6-88 Ash analysis. Measurement of titanium.

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NITRITE CONTENT IN THE SAMPLES COLLECTED FROM IN LAND SURFACE WATERS IN GRADINARI VILLAGE

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Abstract: Water is one of the three vital elements needed for humanity by air and food, but we often overlook its importance (Zăvoianu, 2005). Water pollution is a topical issue with an important impact on ecological balances (http://www.mmediu.ro). Surface water comes from atmospheric precipitation, snow melting and springs, depending on the incline of the soil and the relief. (www.arin .ro) Normally, the water contains small amounts of nitrates. These result from mineralization of organic matter in water. (NIHWM). The origin of nitrates can be highly mineralized soil and rich in nitrogen, soil pollution with organic residues. (this is also the most common way of water pollution with nitrites) (http://www.scientia.ro). For the studies done in Gradinari village, Caras - Severin county, were collected water samples at a depth of 9, 10, 12 meters from the well. The harvesting was carried out both in winter and summer (October, December, February, May, July). For the values obtained from the analyzes carried out on the samples taken, the nitrite content in no case exceeded the maximum permitted limit of 0,50 mg/l.

Keywords: *water, pollution, nitrite*

1. INTRODUCTION

The assessment of the surface water quality consists in the measurement of the physico-chemical, biological and bacteriological parameters, on the control sections, establishing the way the standard norms are observed (Josan N, 2002). Surface water differs according to many characteristics: the flow and its variations (to the flowing), the temperature, the concentration and nature of the dissolved or suspended substances, the biological and microbiological content, etc., each mass of liquid water with its bedding

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and the living creatures being a distinct ecosystem (Alexa E., 2005). Surface waters have many common characters: unlike underground ones, they are typically less mineralized, richer in biological elements, more influenced by other factors (natural and anthropic), more easily polluting, less stable in features, but also have higher capabilities to auto maintain their quality. Comoraste village, has no centralized water supply system.

The water supply of the inhabitants is made from wells, the level of water from the fountains varies from 0.70 m to 14 m, depending on the area (Botoș and Lăzureanu, 2009).

Considering that Ciornovăţ river is not a possible source of drinking water, and from deep drilling can not provide drinking water, the water being sandy clay (Luca and Tărău, 2002).

Not any unpolluted human anthropic water is usable for human consumption, and there is no "standard" natural water to treat as natural pollutants, although the anthropocentric conception has made such a term relevant only for water use to man and not to the understanding of water as a whole (Cuc, 2006).

However, in almost all waters there is life that has adapted to those conditions. The same can not be said about waters with human-modified qualities (Vişan et al., 2000).

2. MATERIALS AND METHODS

The sampling point studied and noted with Gradinari (Fig.1), is a private property fountain in the Caras - Severin county, located in close proximity (about 150 m) of a zootechnical farm. The working technique is based on legislation that measures the ability of substances to absorb or emit light energy at a characteristic wavelength. From a qualitative point of view, the positions of the absorption or emission lines and streams appearing in the electromagnetic spectrum indicate the presence of a certain substance. From a quantitative point of view, the intensity of the emission or absorption bands or tapes is measured for both standards and samples, then the concentration of the analytes.

An important fact to be mentioned and which underpinned the research at this location is that although there is a water supply network in the Gradinari, 70% of the locals use the water from their own fountains.

The water analyzes consisted in sampling groundwater samples from the fountain of Gradinari locality of Caras - Severin, at depths of 9 m, 10 m and 12 m.

The analyzes performed were those of the nitrite content and the steps taken to obtain the experimental results are as follows:

- Sampling
- Preparation of samples for analysis.
- The proper analysis.
- Calculation and expression of results.

For surface sources, water analysis is carried out by harvesting it 2 - 4 times a year during the most critical periods of pollution, namely at minimum winter and lowest summer temperatures (the highest temperatures) and maximum spring and / or autumn flows (after rain or snow melting). The tests used are SPECTROQUANT NITRIT 14776. (AquaMerck)

Conservation of water samples is another important aspect of the harvesting process, it is a concern to preserve samples for analysis because water analysis is of limited value if the samples have undergone physical, chemical or biological changes during transport or storage.

It is generally advisable to pass a very short time - up to 4 hours - between sampling and analysis of water samples. Preserved samples should be kept at 6 ° - 10 ° C. The water sample vials were transported in isothermal packaging to keep them from being hit.

Fig. 1. Sample collecting point at Gradinari location

3. RESULTS AND DISCUSSIONS

For the determination of nitrite content in surface waters, samples from the same water sources were collected at the indicated depths.

The content of nitrites in the surface waters analyzed in Gradinari village ranges from 0.43 mg/l to 0.48 mg/l.

As a result of the analyzes carried out there was no exceedance of the allowed nitrite level below this threshold 0,50 mg/l at Gradinari I, Gradinari II and Gradinari III; but the concentration of nitrite in water is quite high 0.48 mg/l Gradinari I in May month, to the depth of 9 m, respectively 0.48 mg /l Gradinari III in October month, to the depth of 12m, below the maximum admissible limit (Table 1 and Fig. 2).

Table 1. Nitrite content in the samples collected from in land surface waters in Gradinari village

Crt. No.	Village/ depth of harvesting	Month				
		October	December	February	May	July
		mg/l				
1	Grădinari I – 9 m	0.47	0.46	0.45	**0.48**	0.42
2	Grădinari II – 10 m	0.42	0.39	0.32	0.41	0.43
3	Grădinari III – 12 m	**0.48**	0.30	0.32	0.39	0.40

*LMA 0.50 mg/l

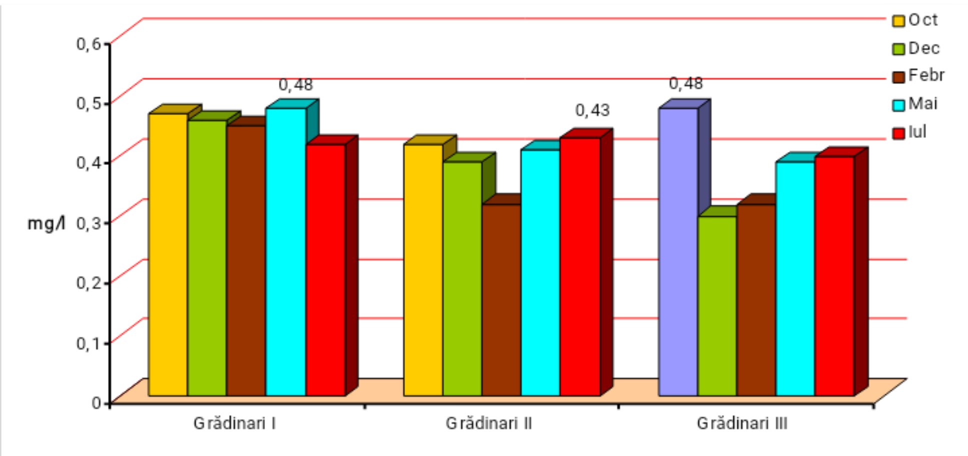

Fig. 2. Representation of nitrite content in the samples collected from inland surface waters in Gradinari village

Nitrite occurs in soils often only in low traces. Forms during nitrification from ammonia or ammonia but is immediately oxidized to nitrate. Microbial degradation processes are formed at different intermediate ammonium stages (ammonification). Water quality does not remain constant over time, but may vary due to many factors, either man-produced (human factors) or natural (which is obviously contributing to human action).

4. CONCLUSIONS

Harmful are in fact nitrites that result from nitrates under certain conditions, where nitrates are reduced to nitrite generating secondary nitrate toxicity.

Chemical compounds of nitric oxide - NO_3 - have a very high incidence in nature. They are present in the soil, in standing or flowing water, in the chemical composition of various plant or animal components, and even in meteoric water.

A cause of exceeding the maximum permitted nitrite limit would have been due to intensive farming through the use of significant amounts of nitrogen-based fertilizers over the years, as well as amendments from fertilizer plants. All of this would have contributed to the increase in nitrite content in surface waters.

As a general conclusion it can be stated that, as a result of the researches carried out for 5 months, it is that in the surface water from the analyzed fountain, it is not polluted with nitrites, being in accordance with the European requirements, it does not exceed the maximum admissible limit of 0.50 mg/l.

The use of the analyzed water drill at Gradinari collection point, Caras-Severin, is recommended to be monitored due to the presence of a content close to the maximum admissible limit.

Pollution with nitrites and not only surface waters occurs through the influence of several factors among which we mention a part of them:

- the passage of water through areas of soluble rock - natural sodium chloride, sulphates, sulphites, carbonates, bicarbonates, which makes the shallow surface or groundwater load with higher or lower amounts of such salts, in relation to the concentration of rocks in such salts and the distance traveled by the water in the leaching process
- the passage of surface water through areas with soil erosion processes - this process causes the water, with a meteoric initial source, to pass through the impurities and various materials that enter into suspension in water and which causes the content of these waters to increase in the nitrite compounds.
- the development of hydrophilic and aquatic vegetation - this type of vegetation can create pollution phenomena especially in stagnant or slow-flowing waters. The intensity of water contamination processes is strongly dependent on the length of the vegetation period and on the rhythm of the metabolic processes of the plants.

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IMPROVE AIR QUALITY MANAGEMENT BY MONITORING AND ASSESSING HEAVY METAL EMISSIONS. CASE STUDY: HUNEDOARA COUNTY, ROMANIA

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Abstract: In the current context of global warming and increased frequency and intensity of severe weather episodes, acute need for sustainable development of the socio-economic environment involving all decision makers is needed. The companies that constitute the pyramid base of the economy must implement policies related to planning, control, assurance and improvement of quality. Air quality is part of total quality management. Monitoring and assessing pollutant emissions are the essential steps for continuously air quality improvement. The purpose of this paper is to analyse emissions of heavy metals (lead, cadmium and mercury) for the period 2003-2016 from the Hunedoara County territory in relation to causes that accentuate or diminish their daily, monthly and annual concentration values. The analysis was based on data provided by the Hunedoara Environmental Protection Agency (APM HD) and the European Environment Agency (EEA). The paper ends with the authors' conclusions based on the monitoring and assessing of heavy metal emissions as part of air quality management.

Keywords: *Total Quality Management, emissions, heavy metals, atmosphere, Hunedoara County*

1. INTRODUCTION

The territory of Hunedoara County is situated in the western part of Romania, being a diverse and harmonious geographic entity, being crossed by the Mureș River and

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its tributaries in the middle, having the southern upper Jiu River, and the north - the upper basin of Crisul Alb making the link between the western counties of Caraș-Severin, Timiº, Arad and Transylvania in the center of the country (Alba, Sibiu), as well as the counties in the south of the country (Gorj and Vâlcea). The administrative-territorial unit of Hunedoara County comprises 7 municipalities, 7 towns, 55 communes and 457 villages with a population of approximately 460,000 inhabitants.

The problems of environmental quality control have been set after mankind has undergone a brief evolution (on a geological scale) has multiplied (often at small intervals, the population has doubled), occupied in one form or another the whole surface of the planet, profoundly, affected or transformed the natural ecosystems and caused an unknown scare until then: pollution (Căpuşneanu et.al., 2015). Industrial pollution addresses the problem of pollution from the workplace to the environmental consequences of the entire earth globe. Industrial pollution of the environment is generally spread by air and water. For the air pollution, both the electricity industry, the gases exhausted by the thermal power plants in the atmosphere, as well as the industrial branches, such as: *the chemical industry and building materials, and especially the ferrous and non-ferrous metallurgy, are to blame.* The most important step in increasing the quality of the environment is the elimination of products that use excess energy and natural products or contain dangerous substances or releases harmful emissions (Constantinescu (Oprea) et. al., 2013).

Thus, there is a need to have a system for monitoring the quality of the environment irrespective of the scale to which it refers or the number of components it encompasses in order to provide an objective image as close as possible to the reality of the environment for adopting correct pollution control and restoration. Being an activity that underpins environmental policies and strategies, monitoring environmental quality requires an organization that takes into account both the complexity of the environment as a global system and the institutional structures that are responsible for it.

Data related to the state and the quality of the environment can be provided by country of different types of organizations, but above all by the National Environmental Protection Agency. The issue of air quality is a major concern for many European citizens and the institutions of the European Union.

2. POTENTIAL SOURCES OF AIR POLLUTION IN HUNEDOARA COUNTY

In Hunedoara County, the potential sources of air pollution are primarily the units for the production of electric and thermal energy, and in a second plan the steel plants, the units for the production of the building materials and the transports etc. The heavy metals emissions in Hunedoara County, according to the inventory of the agency, consist of mercury, cadmium, arsenic, chromium, copper, nickel, selenium, zinc and lead, and attention was paid to mercury, cadmium and lead. In the region, air quality is influenced by the technological processes of the mining industry and the former Hunedoara Steel Plant, currently S.C. ArcelorMittal S.A. Hunedoara, a company that produces tile for pipes, heavy, medium and light profiles, concrete steel, wire and special profiles for mining (http://www.arcelormittalhunedoara.ro). The main sources of pollution in Hunedoara County are presented in table 1.

Table 1. Major air pollution sources in Hunedoara County

Crt No	Source of pollution	Activity	The resulting atmospheric pollutants
1	S.C. Termoelectrica S.A. - S.E. Paroşeni S.C. Electrocentrale S.A. Deva S.C. Acvacalor S.A. Brad	Combustion plant with a rated output exceeding 20 MW	SO_2, NO_X, powder, CO_2, CO
2	S.C. ArcelorMittal S.A. Hunedoara	Installations for the production of steels for continuous casting with a capacity of over 2.5 t / h	SO_2, NO_X, powder, CO_2, CO
3	S.C. Carpatcement Holding S.A. Sucursala Deva	Installation for the production of cement clinker in rotary kilns with a production capacity exceeding 500 t / day	SO_2, NO_X, powder, CO
4	S.C. ArcelorMittal S.A. Hunedoara* * The installation for the production of lime and dolomite was closed on 27.10.2007	Instalation for the production of lime and dolomite in rotary kilns with a production capacity exceeding 50 t / day	SO_2, NO_X, powder
5	S.C. Carmeuse Holding S.R.L. – Point of work in Chişcădaga	Installation for the production of lime with a capacity of over 50 t / day	powder, CO, CO_2
6	S.C. Refraceram S.R.L. Baru	Installation for the production of bricks, refractory bricks with a capacity exceeding 4 m^3 and a density of more than 300 kg/m^3	powder, CO, CO_2
7	Traffic		SO_2, NO_X, CO_2, CO

Source: own projection

Table 2 shows the major sources of air pollution, units under IPPC legislation, as well as greenhouse gases and pollutants emitted in the atmosphere, specific to them.

In Hunedoara County, industrial activities that have a significant impact on air quality are specific to some economic branches with tradition in the area: mining, iron and power generation (thermal and electrical) (http://www.anpm.ro). Mining activities for construction and the cement industry were exploited in quarries located in mining perimeters, on the basis of licenses and exploitation permits. The impact of mining mass activities is manifested by borehole work, sorting activities in sorting facilities, and dumping of tailings on heaps located outside the perimeter with reserves. The steel industry at the level of Hunedoara County was represented during the period 2003 - 2016 by the activities carried out within SC ArceloMittal Hunedoara SA.

The energy industry is represented by S.C. Energy Complex Hunedoara S.A. consisting of: The Mintia Workstation and the Paros Electric Power Plant, resulting in powder (fly ash) having local effects on the environment, through SO_2 and NO_x emissions that contribute to the formation of "acid rain" with regional action and emissions CO_2 that contributes to the "greenhouse effect" increase. Emissions of CO, CO_2, N_2O, NO_X affect the ozone layer.

The pollution of the atmosphere with suspended particles has many sources: first industrial processes, the most important quantity coming from metallurgy and steel, followed by solid fuels, cement factories, road transport, dumps and tailings (Law no. 278/2013). Characteristic for Hunedoara County are mainly tailings dumps and tailings ponds, whose particles are driven by wind over distances of tens of kilometres.

Transport is another factor contributing to air pollution with combustion products: *soot, carbon dioxide, hydrocarbons, lead.*

In order to create an integrative picture of the current environmental conditions, we will present the values of the main indicators related to a month with a high degree of pollution (i.e. August) and the average annual values. These values are compared with the limit values and the alert threshold according to the criteria of Law 104/2011 on ambient air quality (Table 2).

Table 2. The limits for the protection of human health provided by Law no. 104/2011 on ambient air quality

Pollutant	Criterion	Mediation period	Value	Measure Unit	Number of allowed annual exceedances (if any)
Suspended particles, M_{10}	Limit value	one day	50	µg/m3	35
	Limit value	calendar year	40	µg/m3	It's not necessary
Plumb Lead, Pb	Limit value	calendar year	0.5	µg/m3	It's not necessary
Cadmium, Cd	Limit value	calendar year	5	ng/mc	It's not necessary
Mercury, Hg	Limit value	one day	50	mg/m^3	It's not necessary

Source: own projection

The Hunedoara Environmental Protection Agency is responsible for the annual inventory of emissions of air pollutants - emissions from both fixed sources such as energy burning and transformation industries, non-industrial combustion plants, burning in the processing industry, production processes, extraction and the distribution of fossil fuels and other products, waste treatment and disposal, agriculture, forestry, etc., as well as from mobile sources such as road transport, other mobile sources and machinery. Thus, in Hunedoara County, the Hunedoara Environmental Protection Agency operates five automatic air quality monitoring stations included in the National Air Quality Monitoring Network. They are located in Deva, Hunedoara, Călan, Vulcan.

Consequently, the urban station monitors the indicators: NO_x/NO_2, SO_2, CO, O_3, VOC, PM10, Pb, and the industrial base stations monitor the NO_x/NO_2, SO_2, CO, O_3, PM10, Pb indicators. The values resulting from the measurements corresponded to the tolerance limits established by the Law no. 104/2011

Heavy metals (mercury, lead, cadmium, etc.) are compounds that cannot be degraded naturally with a long retention time in the environment and are dangerous in the long run because they can accumulate in the food chain. These can cause muscular, nerve, digestive disorders, general apathy.

In Hunedoara County, the total area affected by industrial activities is over 10,000 ha. These branches of activity generate waste requiring final disposal and municipal waste disposal is carried out on sites that do not currently meet the environmental protection requirements.

3. THE MAIN TRAITS OF POLLUTANTS - HEAVY METALS: CADMIUM, LEAD, AND MERCURY (CD, PB, HG)

There are 35 metals that are present in the workplace as well as in dwellings. Of the 35 metals, 23 metals are considered heavy, such as antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, platinum, silver, tellurium, thallium, tin, uranium, vanadium and zinc. The study has focused on three elements, namely cadmium, mercury and lead.

The main features of **cadmium**: in nature is found as combinations (CdS) in zinc ores; is highly toxic; they are used in alloys to increase the resistance of metals to corrosion agents, especially seawater; the most important source of cadmium contamination is industry, notably the non-ferrous metals industry and the combustion of fuels; is a strong enzyme inhibitor, especially with sulphuric enzymes.

Main features of **mercury (Hg)**: is one of the metals known since antiquity, being known as silver; the classical method for the preparation of mercury consists in roasting the cinnabar in the oven at 600-700℃, in the presence of air when the metal SO_2 results (since the resultant mercury oxide is thermally unstable):

$$HgS + O_2 \rightarrow Hg + SO_2 \tag{1}$$

followed by cooling the mercury vapour in water-cooled sandstone condensers.

Sometimes, especially in the case of small-scale mining, the cinnabar is heated in the oven at 600-700^{o}C, either with lime:

$$4HgS + 4CaO \rightarrow 4Hg + 3CaS + CaSO_4 \tag{2}$$

either with iron crunch:

$$HgS + Fe \rightarrow Hg + FeS \tag{3}$$

is used in some electrolysis cells as a mercury cathode, in the extraction of gold and silver in various precision instruments and apparatus such as: thermometers, barometers, manometers, densitometers, high vacuum pumps, etc., in the preparation of medicinal ointments, preparation of mercury fulminate, cinnabar, in AC rectifiers, ultraviolet lamps, amalgam preparation; in pure form, but also in compounds it is very toxic, and ingestion or inhalation can ultimately lead to respiratory arrest and death.

Main features of **lead (Pb)**: it has toxic effects; known and used since ancient times, lead, has constituted and is a major environmental pollutant; its accumulation in large quantities in soil as a result of pollution results in passive absorption in plants; is toxic to the brain, kidney, reproductive system and cardiovascular system; exposure to lead causes disturbances of the intellectual function, which is especially dangerous for children.

Pollution of the atmosphere with suspended particles has many sources: first industrial processes, the most important quantity coming from metallurgy and steel, followed by solid fuels, cement factories, road transport, dumps and tailings. Characteristic of Hunedoara County are mainly tailings dumps and tailings ponds, whose particles are driven by wind over distances of tens of kilometres.

4. RESULTS BASED ON ANALYSIS OF ENVIRONMENTAL QUALITY POLLUTION FACTORS WITH CD, HG AND PB

The contribution of energy activity sectors to heavy metal emissions in Hunedoara County for the period 2003 - 2016 is summarized in figure no. 1.

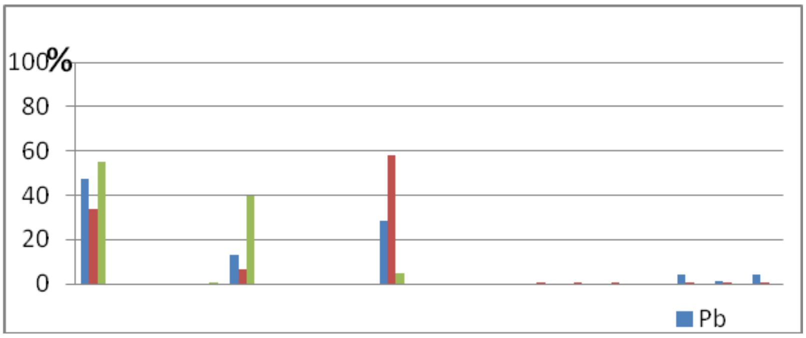

Fig. 1. Contributions of energy activity sectors to heavy metal emissions in Hunedoara County (*Source: environmental reports 2003-2016, APM Hunedoara*)

From the distribution of heavy metals emissions by sectors of activity it can be noticed that: the largest share of lead emissions comes from the production of electricity and heat (47.29%) and from residential heating (28.53%); the largest share of cadmium emissions comes from residential heating (57.85%), followed by the production of electricity and heat (33.55%); the largest share of mercury emissions comes from the production of electric and thermal energy (55.05%) and from combustion in industry (39.54%).

The contribution of the activity sectors to heavy metal emissions (Pb, Cd and Hg) in Hunedoara County between 2003 and 2016 is summarized in Figure 2.

From the data shown, the highest share of Pb, Cd and Hg comes from the energy sector and the industry sector.

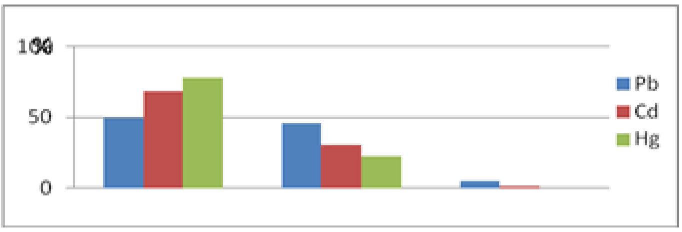

Fig. 2. Contribution of the activity sectors to heavy metal emissions in Hunedoara County (*Source: environmental reports 2003-2016, APM Hunedoara*)

The contribution of industry subsectors to metal emissions, at the level of Hunedoara County in 2016, is shown in Figure 3:

Fig. 3. Contribution of industry sectors to heavy metal emissions in Hunedoara County (*Source: environmental reports 2003-2016, APM Hunedoara*)

The share of heavy metal emissions in the industry subsectors, related to Hunedoara County, comes from the production of cast iron and steel. The contribution of transport vehicle types to heavy metal emissions (Pb, Cd), at the Hunedoara County level in the period 2003 - 2016, is presented in figure no. 4.

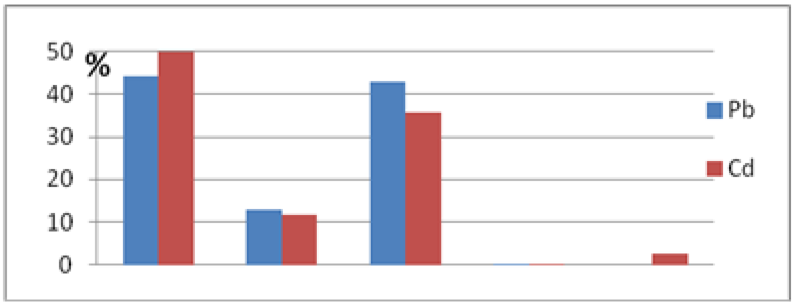

Fig. 4. The contribution of vehicle types to heavy metal emissions in Hunedoara County (*Source: Environmental reports 2003-2016, APM Hunedoara*)

The transport emissions of Pb come mainly from passenger cars (44.18%) and heavy vehicles (42.88%), the rest being: light vehicles (12.80%) and mopeds (0.14%). In the case of Cd, the highest contribution is given by cars (49.79%), followed by heavy vehicles and buses (35.75%), light vehicles (11.74%), railways (2.55%) and mopeds (0.17%).

Emissions of heavy metals in Hunedoara County, estimated between 2003 and 2016 by the CORINAIR and AP-42 methods, and as of 2009 according to the latest EMEP/EEA Air Pollutant Emission Inventory Guidebook in the table 3:

Table 3. Emissions of heavy metals (kg/year) between 2003 and 2010

Hunedoara County	Year							
	2003	2004	2005	2006	2007	2008	2009	2010
Mercury emissions	2248.92	407.36	180.54	252.59	330.16	300.24	133.47	111.26
Cadmium emissions	213.07	411.22	60.64	62.65	68.07	41.93	86.30	72.74
Emissions of lead	1164.38	7546.49	7035.94	3383.91	2697.17	2122.58	982.49	1841.03
Total emissions	**3626.37**	**8365.07**	**7277.12**	**3699.15**	**3095.40**	**2464.75**	**1202.26**	**2025.03**

Source: own projection

The above table shows a decrease in heavy metal emissions since 2009 compared to previous years, as this year was applied the CORINVENT 2009 calculation methodology that provides for different emission factors.

5. CONCLUSIONS

Air quality in Hunedoara County continues the general trend of improvement in recent years. Pollutant monitoring is a necessary part of any environmental management system, which is the basis of a fully-informed decision-making process and the development of environmental management strategies.

Since, at the level of Hunedoara County, the energy sector brings a significant contribution to the pollutant emissions, the rehabilitation of the energy blocks will lead to the reduction of atmospheric emissions. Supporting, enforcing and enforcing corrective measures leads to streamlining the control process, but also to the quality of environmental investments, including the performance of efficient management and the achievement of notable financial performance.

The level of emissions of pollutants released into the atmosphere can be significantly reduced through the implementation of environmental policies and strategies as follows: greater use of renewable energy sources (wind, solar, hydro, geothermal, biomass); replacing classic fuels with alternative fuels (biodiesel, ethanol); the use of high energy efficiency installations and equipment (low consumption, high yields); implementing a program for afforestation and creation of green spaces (CO2 absorption, fine dust retention, oxygen release into the atmosphere).The objectives of the monitoring systems also include aspects related to process optimization, verification and compliance with legislative provisions, such as admissible emission limits. Many pollutants known to have effects on human health gradually fall under regulated control.

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THE UNDERGROUND SPACE, A SOLUTION FOR THE PROTECTION OF THE ENVIRONMENT

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Abstract: The research, concerning the development of underground facilities worldwide, it indicates that both a favourable environment for the use of the underground space (or space location understood as great) and a boost to the adoption of the method are required to achieve the underground construction of major underground facilities. A major incentive for the use of underground space is growing international concern on the environment, which led to rethinking future urban construction and industrial. It is clear that increased pressure on the use of terrestrial lead to two trends already present in many countries, or the construction of high-rise buildings or use scale growing facilities of underground space, variant seems however, it is the most advantageous. In this context it is important to plan new type of underground facilities wisely. Planning must be effectively controlled and used to maintain the natural surface and side effects involved in the development of underground projects are anticipated.

Keywords: *underground space, the environment, the use of underground space, construction*

1. INTRODUCTION

The increasing world population and rapid development of modern society will have a significant impact on the livelihoods of people in the future, leading to higher living standards, increasing consumption of food, energy and minerals. Due to population growth, urbanization and economic growth this earth must now support transport systems extensive industrial development and trade and growing demand for housing, so that the area under agriculture decreases gradually since the seats flat and generally fertile they initial development was places historically.

A major incentive for the use of underground space is growing international concern on the environment, which led to rethinking future urban construction and industrial.

The largest underground city in Cappadocia, Derinkuyu was discovered only in 1965, when one of the region's residents cleans up in a room of his house.

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Finally, archaeologists and speleologists have discovered that behind the wall hiding a real underground city, which stretched at least 18 stories underground to a depth of about 85 meters, and can accommodate about 30 000 people.

In fact, experts have not fully explored even today underground city of Derinkuyu.

2. THE CURRENT STATE OF THE UNDERGROUND SPACE

Environmental damage caused in the last century has significantly reduced quality. In this respect good knowledge of damage caused to the environment in developed countries use obsolete technologies affecting the environment in poor countries with environmental pressure due to overpopulation and increasing needs, promotes better understanding of the phenomenon of environmental pollution and enables us to take appropriate action to protect it.

But environmental damage is done not only because of human error or technical accidents but also due to cultural approaches inadequate or blind economic policies.

Accumulation of quantities in recent years increasingly more waste owing to increased human activities, process reported worldwide, raises very important economically and environmentally.

Thus, it is estimated that between growth rate and the volume of waste there is a proportional relation, which contributes to the worsening conflict in the modern age of technology, on the one hand and ecology on the other. The massive increase discharges of waste and toxicity of a good part of their content jeopardizing the ability of the environment to assimilate them.

The emission and waste discharge into the environment of the initial stage of the process is pollution, followed by reaching the ambient concentrations in the quality of the biological environment.

Therefore a fundamental objective of any policy and strategies for environmental protection is to reduce the amount of waste from production and consumption patterns as a result.

Such an objective can be achieved by way of recycling, reconditioning or recovery of waste and deposit them in appropriate conditions to eliminate any possibility of environmental pollution. But desirable as better integration of environmental concerns into consumption and production schemes.

According to statistics and international studies, the quantities of waste generated in each country and the average per capita was related to the degree of development and urbanization, the type of technology applied in the production of specific and consumption patterns, income levels and lifestyle population.

However, the level of development and civilization leaves its mark on the business of environmental protection waste pollution.

Effective waste management in the context of sustainable development refer the following dilemma: waste disposal or recovery of the amount remaining under the restrictions of cost and the environment.

The aim in waste management is to maximize the preservation of non-renewable resources and neutralizing negative effects on the environment.

So the concept of the cultural sector can be characterized by including waste issues within the general actions for environmental protection, given that any waste which is not used or neutralized, pollute the environment.

Currently in developed countries of the total expenditure on environmental protection:

- 20 ÷ 25 % of which are intended to be recovered by recycling useful minerals and the costs incurred are recovered;
- 75 ÷ 80 % are for the collection, neutralization, elimination and / or economically non-recoverable waste disposal.

In Romania, the costs for the collection, transportation, disposal and storage of waste solids is about 27 % of the total expenditure for environment protection, reflecting a relatively small and insufficient concern.

The ratio of investments for the recycling of waste and waste pollution protection is negligible, less than 1 % of the total investment. Meanwhile developed countries spend for this area, between 5 and 15 % of total investments.

Reported per capita total annual waste in Romania is about 12 tons compared to about 10 tons as the media representatives on all countries in Western Europe.

The differences between the two levels can be explained by: character structure of the economy and lack of funds; outdated technology; lack of continuing concerns for the environment.

The highest weights are held in our country waste resulting from underground mining and quarrying - over two fifths. In terms of the amount of waste dumps and tailing ponds is the most important source of environmental pollution. Evaluate all over the country, about 360 million tons, which make up the waste deposits and tailings ponds current production resulting from the activity occupies an area of 11.600 hectares, which is equivalent to about 0.08 % of the total agricultural area of Romania 0.12 % of total arable land.

Of the total area occupied by waste dumps and tailing ponds have been provided up to now, about 9 %. If they are supplemented ash, slag and waste ore metallurgical processing, shows that over 70% of solid waste pollution due to industrial activities freely. In Romania of over 2 million tons of waste annually, representing about 95 % of industrial waste. (Wegner, 1993) Although difficult and costly removal and disposal remains the central issue of environmental strategy.

Methods of waste disposal, the most used is deposition on land or burial ground (especially for municipal waste, in Romania there are currently only two landfills and no ecological waste incinerator). So costs are low, this presents a high risk of pollution by high potential for groundwater contamination, soil and explosion through gas accumulation.

In these circumstances the main objective of sustainable management of waste is to eliminate as far as possible the risk of pollution by pretreatment of waste deposited or depositing them in complete safety or in underground facilities, specially built for this, but that society contemporary Romania can not allow, particularly in economically, either by use of underground spaces resulting from the mining activities of various useful minerals.

Today suggested the need to calculate economic benefits by assessing the feasibility of all actions that can change the environment. Thus, a proper economic analysis can only be one that will take into account the environment.

This is a problem for both people and industry, and acceptable solution must be based on acquiring the already serious problems affecting quality of life and future can endanger life itself.

Using underground space it has been recognized as one of the most important ways of solving difficult problems of waste management.

In the face of immense pressure acting on the environment, using underground is a safe and most often only economically, given a correct design, safeguard the environment.

It must however be borne in mind that the underground facility may affect the environment both positively and negatively, so the role of design and studies to be carried out is precisely to maximize the positive effects and to eliminate or minimize the negative ones.

3. THE DIRECT BENEFITS ON THE UNDERGROUND SPACE

Using underground space, in compliance with its copy of the surface results in a large number of direct benefits, most important being (Stefan, 2006):

- First point
- temperature is approximately constant in the ground which is an advantage for storage of certain products;
- moisture is easily controlled, and the quality of groundwater can be kept without difficulty;
- safety is excellent in terms of fire, flood, hurricane, big rain and snow;
- proliferation of insects and bacteria is better controlled than in the conventional storage of goods;
- damage and loss of production are considerably reduced material;
- land area is protected from pollution of the gas, liquid and solid. It also avoids aggression and destruction of forest land, flora and fauna.

Because of these advantages, today reported a large number of uses of underground spaces for storing: various documents, fuel oil, compressed air and other sources of energy, water, food and agricultural products, weapons and weapons sludge from waste treatment plants, spent fuel from nuclear power plants and atomic other radioactive waste, and municipal waste.

Also the underground space can be arranged to house museums, swimming halls, vaults of banks, research centres, oil refineries and various waste recycling centres, hydroelectric and atomic power plants. If atomic nuclear plant at Chernobyl was built underground as the vast majority of the damage caused by the explosion in April 1986 could have been avoided. Due to environmental constraints rising that are currently imposed on the various laws in most developed countries, they have been made in recent years, a large number of projects underground, while many others are under construction or stage conception.

There is now a general attention to these types of engineering solutions and many countries have begun to consider the underground space as a "resource" that must be treated and managed with care. Some developed countries have decided to evaluate this important resource in their territory by measuring underground spaces natural of abandoned mines or other excavation underground to develop large-scale projects in order to seek and implement new solutions for utilization of these resources.

Underground environment is not only an object of potential impact but also an element of moderation, which becomes clear when hosted arrangement aimed at protecting the environment such as water treatment plants or landfills.

Changes in the type and geographical distribution of the industry could lead to conflicts of land use: Also, changes in the environment, energy and operating costs in the industry may require new strategies and industrial policies.

Underground space can resolve some of these conflicts, and change long-term industrial strategy should consider the underground option. Underground disposal and storage projects are feasible, economically viable and can be clearly provides environmental benefits.

It therefore appears objectively as a detailed analysis, the environmental benefits related to the use of underground spaces are considered in economic terms, can often allow a change of perspective that compensates very high costs for the execution ground.

Practice environmental impact assessment must become an essential component in the design of all facilities to help address these enormous fears of humanity.

Benefits resulting from the achievement of underground facilities not only environmental benefits, but applies to:

- anyone directly involved in the work (client, user, company building);
- economic-social and people directly or indirectly involved due to the effects caused by construction work.

If achieving underground facilities between itself and the environment can be distinguished both positive interaction and negative, but it is important that the design work specific to succeed in harnessing all those positive interaction, to control and moderate the intensity of the negative in order to successfully use such arrangements and to eliminate the possibility of undesirable uncontrolled further, that through their action could cause damage to the environment.

Industrial activities could become technically, economically and legally feasible and environmentally advantageous placing them underground would be: deposits of oil, petroleum products and natural gas; deposits of industrial and consumer goods; cold storage of food; waste disposal mining, metallurgical, construction, household and radioactive; wastewater treatment systems.

Also the underground space could be used for recreational facilities such as museums and different places, but also for security deposit and religious facilities, while identifying appropriate sites and assessments correct.

4. EXAMPLES OF THE USE OF UNDERGROUND SPACE

4.1. For residential use

Uses the underground space as living space is probably the oldest of its use by people. Archaeological and anthropological research found many fossils in caves that serve as shelter in various parts of the world. Thus two of the remotest discoveries of cave dwellings are Qafzeh in Israel, dating back 92 000 years ago and Klasies River Mouth in South Africa where he was born the theory of anatomy, that people lived from 60 000 ÷ 120 000 years ago.

In many countries and regions of the world can give examples of historical settlements underground. The main reasons for the use of underground space for residential seem climate, there is a geologist and suitable topography, the need for protection against intruders and the existence of previous examples.

Settlements included significant underground dwellings carved in stone in Cappadocia in Turkey, which reached its peak in sec. X - XI of the Byzantine period.Two of the most famous underground cities are Kaymakli and Derinkuyu Anatolian which included civil engineering, ventilation shafts and tunnels connecting several kilometers excavated existing volcanic tuff.

In 1963, British archaeologist James Mellaart discovered a fresco now considered the oldest ever discovered landscaping work. Dating back 8000 ÷ 9000 years ago, the painting is also the oldest work of art made on a built area of people - a wall made of bricks plastered with mud. Fresca measuring 2.5 meters by two cones depicts a volcano erupts while being placed on a structure composed of multiple packs apparent. Soft volcanic tuff enough to allow a man to dig through it with a spoon. When exposed to air, however, the material is solidified. Historical evidence shows that around 700 before Christ people armed with iron tools digging into the ribs of Cappadocia to build their homes. Nobody knows how many underground cities in Cappadocia hide. Have so far been discovered eight cities and many smaller villages, but certainly there are others hiding underground. (***)

4.2. Derinkuyu - the largest and most mysterious underground city discovered

One of the characteristics of the underground cities Cappadochia is set. It is known that in this region there are over one hundred underground settlements, many of which are open to the general public, however. Derinkuyu underground city is located in the eponymous town at a distance of 40 km of Goreme, Turkey. Originally built in soft volcanic rock in Cappadocia by Phrygians in the eighth and seventh century BC, the underground city Derinkuyu was expanded and developed in the Byzantine period. The city was connected with other underground cities through long tunnels of several kilometers.

To accommodate between 3000 and 50000 inhabitants. The complex has 11 levels. There are approximately 600 outlets by the city, hidden courtyards or under buildings. The city is about 85 m deep underground. It comprises the usual rooms found in underground cities, (churches, winery, living rooms and food storage, etc.). In addition, a large room that presents an arch, located in the 2nd, was a Christian missionary school rooms left were used for the study.

Derinkuiu city contains about 15 000 channels supplied fresh air ventilation in the depths of subterranean city. Vents that have a depth of 55 m were used as fountains.

The extensive network of passages, tunnels, corridors inclined linking family rooms and common areas where people puteu meet, work and pray. Level 3 and 4 are vertical scale. This passage leads to a cruciform church, which is the lowest.

Derinkuyu underground city was where the early Christians hid from the region, who escaped from persecution carried out in the Roman Empire.

One of the tunnels discovered by cavers is wide enough to allow simultaneous passage of three. Going along it, the scientists found that the tunnel connects to another underground city located at 10 kilometers away. Moreover, several findings suggest that at some point, all Cappadocia was linked to a hidden network of underground tunnels. Today, many people in the region use these tunnels to post cellars.

Archaeologist discovered that cities were lit with torches or oil lamps in, producing enough heat to maintain the temperature at a pleasant level. Moreover, it is likely that these underground cities have been used first as a winter shelter. In time, however, as the Hittites, Assyrians, Romans, Persians, Byzantines, Seljuk Turks and Christians found through these caves, each of these civilizations has deepened and extended them for another purpose: the defense. Moreover, scientists have concluded that the Seljuk Turks and Christians extended the original rooms, dug in prehistory, so as to allow the creation of underground stables for horses.

These civilizations were not the only ones considered cities as a good shelter underground war. In 1990, when the Gulf War was in full swing, the Turkish authorities have considered using underground shelter against bombs cities where conflict would be expanded regionally.

The underground city of Derinkuyu, underground stables housed below the floor feed. Below are found the communal kitchen equipped with furnaces earth below a ceiling of 3 meters with holes for ventilation. These bore holes specially drilled smoke tunnels, so that it reaches up to 2 kilometers away, to fool the opponents.

In Australia many mining towns have placed a number of housing and community buildings underground to escape the severe heat outside. These examples include Coober Pedy mining towns of White Cliffs and Andamooka.

In France and Spain sec. Twentieth use of underground spaces residential caves link to use as holiday homes, many of which are furnished to the highest contemporary standards.

The energy crisis of the 70s of the XX century generated a strong public interest in developed countries about the benefits of energy conservation in underground structures, so there have been some developments in the US multifamily along highway in Minneapolis.

4.3. Recreational use

Perhaps the most famous and widespread use of underground spaces for recreation is linked to the exploitation of caves for tourism, and the inclusion of tourism of the old me. Underground recreational facilities include sport facilities and community centers in many parts of the world. Types of facilities used include swimming pools, gyms, hockey halls and sports facilities with multiple purposes. Norway Gjovik swimming pool and gym Kannusillanmaki sports center in Helsinki, Finland are examples of potential underground recreational facilities.

Georgetown University, Washington, a facility for sport has been extended under existing football field. In China, Hanzhou city has bars, a ballroom and multiple rooms designed for the amusement of children in the underground space and underground city of Hangzhou has a theater with 1800 seats, used and defensive end. Retretti concert hall in Finland is known around the world for acoustic performance achieved. In Japan, the underground space of the former limestone mines Ohya is a place often used for art exhibitions and numerous shows. In Poland mine in Wieliczka is famous for its use as a museum and concert hall.But the examples are many and countries in Central and Western Europe. In Romania are known recreational and health centers for curative value, Slanic Prahova salt mines and mine. These uses are specific underground voids created from solid salt extraction methods. Thus formed underground spaces are large and very large, they have constant temperature (12 ^{0}C) and humidity of approx. 50%.

4.4. Use for urban development

The most significant examples are present in Montreal and Toronto, consisting of large parking lots and underground pedestrian interconnected systems that allow movement in much of the area under the city without exposure to inclement weather or road traffic. They also contain shopping areas with the most fashionable stores.

Another example of an integrated urban development is complex underground Les Halles in Paris. The complex covers 100 000 m^2 and extends on four levels below ground, keeping the area a park surrounded by old and beautiful historical sites and architectural and includes subway, streets, parking lots, a great area for shopping, recreational facilities and a pool swimming. Japan has also a long history of development of underground shopping centers.Today more than 20 Japanese cities have shopping complexes and underground infrastructure services.

There is: using the library, offices, educational institutions, use for industrial facilities, use for military and civil defense facilities, religious use and the use of storage, see in (Georgescu and Ciolea, 2017).

5. THE FUTURE UNDERGROUND

In the XXI century, a growing group of visionary engineers and architects for increasingly more often to underground. But this time, why not escape religious persecution - their goal is to escape the crowds. (***)

2018 will start construction of 9 billion a city underground, just below the famous canals of Amsterdam, which will include places for shopping, relaxing spaces and parking. Singapore, Toronto and Frankfurt plan also major underground development.

Not only will shop around underground, but Mexicans will live soon there.

A "sky-ground" on 65 levels proposed for Mexico City will descend about 300 meters below the main square. Inverted pyramid created by Bunker Arquitectura, will have a core of ten levels of glass that will send light to the 10 levels of housing, stores 10 levels and 35 levels of offices. Although not necessary to worry about miscreants Romans, living under the earth's surface has some distinct advantages.

"If you take into account phenomena such as natural disasters, where would you rather be: the 50th floor of a tall building or underground?", says Professor Samuel Ariaratnam engineer at the University of Arizona, one of the authors of a report by the National Academy of Sciences of the United States about the future of urban development underground, and if the surface climate change will create catastrophic conditions, then a shield of earth and stones, several meters thick, would be more desirable than a balcony with a view.

As recognizes Ariaratnam, down construction cost is higher than building up: "I think I see skyscrapers reverse in my lifetime," he says. But long term, the benefits begin to appear, and underground becomes a desirable place to live. "Look at hot and wet climates or the very cold. Who would want to hang out? "

One day, you could find and parks in the depths underground. There are proposals in the New York park "Lowline" in a huge area remained without use after scrapping a system of trams in 1948. The name is inspired by the High Line park, which was built on an abandoned rail system in western Manhattan. Mirrors and optical fibre cables will bring daylight into these caverns. Tubes reflectors will play a key role in this project by focusing sunlight above. These innovations will allow grass, bushes and even trees to grow on the surface of the Earth.

Existing underground developments have shown how the phenomena that we associate with the surface can be brought under the ground. Sanford Underground Research Centre - a complex of laboratories in South Dakota, which has levels from 90 metres depth to almost 2500 meters - the architects have worked with psychologists to try to make the environment as pleasant as possible. The screens show images of blue sky and ventilation systems create air flows to mimic the surface breezes. The designs are intended to prevent psychological problems.

But PhD. Raymond Sterling, a professor at Louisiana Tech and an expert in underground spaces, suggests that life at this level should be no problem. "Most people have no problem in using the London Underground or be in a room without windows during a concert", he says. "If people find a reason for this or if there are physical benefits to be underground, they can accept it."

6. CONCLUSIONS

Underground space is an important resource whose use land began long before the birth of self-consciousness of man. Underground space in modern times began to be used widely overseas in the US first, then this type of use has grown in Western Europe and Japan. Spaces are underground link to geo-mechanical parameters identification, mining, favourable economic and political, which then serve to assess the feasibility of the proposed comparative technical schemes.

In Romania the lack of use of underground space facilities, consciously or using it enough, can be caused by: geology incorrect perception that the country is poor; absence of a strategic planning of the use of the subsurface; the insufficient funds allocated to this area; absence or insufficient knowledge of the advantages of the underground space; the absence of the necessary technology; tracking failure to respect the environment. The research in Romania in this direction should include the following objectives: presentation of the key points of technical considerations, geological and economic acceptance or rejection of the use of underground spaces; assessment of geological conditions, market and legislative framework and administrative process related to the use of underground space across the country.

In Romania analysis, particularly the following areas with direct implications in economic, social and environmental development should be prioritized: storage of natural gas and oil products; industrial warehouses and consumer goods; food warehouses; waste deposit; systems and storage elements and operation of wastewater treatment plants give industry and the household; storage of agricultural products; storage of raw materials and different materials.

In this regard should be given to re-use mines or excavations developed specially for this purpose, there is a large worldwide experience in the use of underground space even weak and intensely fractured rocks.

Underground space is recommended for residential, religious, recreational, urban development, library, offices, educational institutions, storage for industrial facilities, military facilities and civil defense.

In the process of using underground space must analyze many factors geological, geo-mechanics, mining and economic and solely by test results complexes on their decisions can be location undergrounds various social functions or industrial normally locates the surface.

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CLAY LINER DESIGN OF A LANDFILL IN JIU VALLEY BASED ON DETERMINISTIC & STOCHASTIC RISK ANALYSIS

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GELU MADEAR [2]

Abstract: Coal Mining Industry in Jiu Valley left some abandoned open pits which represent a significant liability to the environment. One solution for the rehabilitation of these sites would be the reuse of the open pits as landfills for Municipal Solid Wastes (MSW). The paper presents the proposed solution for the engineered barrier and leachate management system. Generated volumes of leachate were calculated based on local precipitations data using the most advanced hydrological modelling software for designing landfills and evaluating potential leachate seepage to the groundwater table, used as input parameters in Hydrogeological Risk Assessment (HRA).

Keywords: *coal mining; landfill; open pits; environment; risk analysis; HRA.*

1. INTRODUCTION

To comply with the Landfill Directive (1999/31/EC), Groundwater Directive (80/68/EEC), Water Framework Directive (2000/60/EC), Drinking Water Directive (80/778/EEC), a thorough Hydrogeological Risk Assessment (HRA) should be carried out before applying for permitting to the Environment Agency. To carry out the HRA, a Conceptual Site Model has been developed based on existing information on geology and hydrogeology, as well as mining records.

Clay liner design was based on the impact of existing contaminants in leachate to environmental receptors – the aquifer (Receptor 1) below the site within the bedrock and an imaginary borehole (Receptor 2) outside the landfill area. We have assessed the impacts for List I substances at Receptor 1 and the impacts for List II substances at Receptor 2.

The Source-Pathway-Receptor (SPR) linkages as derived from the Conceptual Site Model (CSM) were used in a multi-tiered Hydrogeological Risk Assessment.

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The first phase consists of a Simple Risk Assessment using deterministic approaches. For the worst-case scenario, analytical solutions are solved in a deterministic fashion using conservative input parameters, assumptions, and methods.

The second phase uses a Complex Risk Assessment which is carried out using stochastic techniques to an analytical solution. Monte Carlo simulations are used to evaluate and predict leachate concentrations and elevations during the operational phase of the landfill and to estimate advective fluxes from the landfill. Both advection and diffusion are possible contaminant migration mechanisms throughout the lifecycle of the landfill.

The use of probabilistic distribution functions addresses the uncertainty of the input parameters, and the results are also returned as ranges and defined according to the probability of occurrence. The 95th percentile values are used as outputs from the model, which are representative of the reasonable worst-case performance of the landfill. The Romanian Drinking Water Standard has been used as the Environmental Acceptable Levels (EAL).

2. BACKGROUND INFORMATION AND SITE DESCRIPTION

Jiu Valley is known to be one of the most important mono-industrial areas in Romania, due to the coal mining industry. In addition to the benefits of this activity, the Jiu Valley is now paying a fairly high tribute to all years of exploitation, namely the acquisition of a large number of degraded land areas. However, the disadvantage of the existence of these surfaces may turn into an advantage if it is taken into account that they can serve as ecological landfills.

An example of degraded space from the mining activities in Jiu Valley, which can be a potential site for the ecological landfill, is Victoria Open Pit (VOP) in Lupeni (Fig. 1 a and b).

Fig. 1. (a) Victoria open pit; (b) Victoria open pit footprint

VOP is located approximately 2 km north-east of Lupeni City Center, in Petrosani Depression, Hunedoara County. The latitude of the centre of VOP, Jiu Valley is N45.3765°, and the longitude is E23.2298°, with GPS coordinates 45°22’35.4’’ and

23°13’47.28’’. The open pit is delimited at the east by Vulcan Minefield, to the west by the Barbateni Village, having Hateg Mountains to the north and Valcan Mountains to the south. A railway runs approximately 3 km south along DN66A. VOP is within a hilly topography, in the western part being covered by dense forests and meadows to the east. Nearby, at approximately 750 m southeast and 1.5 km southwest, there are few urban areas with buildings and some minor roads serve the area and link to the site. Jiul de Vest river is located approximately 3 km south of the VOP and also two small brooks - Bolosinestilor and Plisabeia - runs nearby.

3. GEOLOGY, HYDROGEOLOGY AND ENGINEERING GEOLOGY

Based on the available background information, the following superficial deposits and strata are expected at the site and its environs and are described in Table 1, from the youngest to the oldest:

Table 1. Summary of geology

System – Series - Age	Formation
Neogene – Miocene - Burdigalian	Sandstone, Reddish and Greenish/ Greyish Clays, Carboniferous Schists
Paleogene – Oligocene - Chattian	Sandstones, Marls, Bituminous Marls, Disodilic Schists, Carboniferous Schists and Coals
Paleogene – Oligocene - Rupelian	Clay, Marl, Sandstone, Sandstone Containing Bituminous Clay, Coal

Burdigalian - Hanging Wall Horizon - This horizon is made up of a conglomeratic series in alternation with sandstones, reddish and greenish/ greyish clays, sometimes with plants and carboniferous schists. In Lupeni area there are three distinctive conglomerate layers, which divides towards the east, becoming more like sandstones, with some intercalations of marls, marly limestones, green clays and yellow sands slightly cemented.

Chattian-Aquitanian - Productive Horizon - This geological formation is comprised of a series of micro-conglomerates, sandstones, marls, bituminous marls, disodilic schists, carboniferous schists and coals. Coals are located at various depths within this horizon and are represented by 25 layers of hard coal and brown coal. At the upper part of the horizon, there is an alteration of clays, sands, sandstones, carboniferous schists and coals.

Rupelian - Inferior Conglomeratic Horizon - Conglomerates represent approximately 75% of the total thickness of the formation comprising grey quartzitic rocks, gneiss and pegmatites, which are embedded in a reddish clay layer. On the west side of the Jiu Valley, at Lupeni, Vulcan and Uricani there are green sandstones and white-yellowish limestones distributed randomly. Rupelian deposits are located at the boundary of Petrosani Coal Basin, but there are not found on its north-western side - north of Lupeni, where Burdigalian might overlay them.

Tectonics - Petrosani Coal Basin is embedded into the tectonic ensemble of Southern Carpathians, having in its structure all the three distinct units: Getic Terranes (Nappe); Danubian Terranes (Unit); Neozoic Sedimentary Deposits. The Danubian and Getic Terranes consist of shallow-water marine and non-marine Mesozoic rocks that rest on Paleozoic and Precambrian sedimentary and crystalline rocks. The main tectonic element is represented by the fact that rocks of the Getic Terranes have been thrust eastward over rocks of the Danubian terrace, along the Getic thrust fault, resulting in a synclinal basin.

A geological cross-section and the geological map of the region are presented in Fig. 2 a and b.

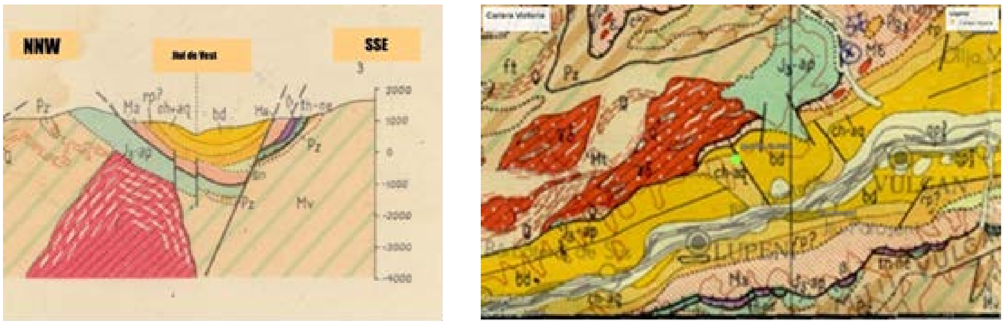


Fig. 2. (a) Geological cross-section; (b) Geological map of the region

4. QUANTITATIVE HYDROLOGICAL RISK ASSESSMENT (QHRA)

Victoria Landfill is proposed to be constructed to receive Municipal Solid Waste (MSW) from nearby towns. A former open-pit is now a potential location for a landfill and would be relatively small in size. Environment Agency requires that as part of the waste management licensing process, an assessment is carried out to predict the likely impact on groundwater and compliance against the requirements of the Groundwater Directive.

Separate risk assessments are to be undertaken for other processes including migration of, and exposure to landfill gases, construction and durability of engineered barriers and leachate management systems and impacts on ecological systems. A hydrogeological conceptual model (Fig. 3) has been developed based on historical mining data and groundwater levels, and the outline design of the proposed landfill.

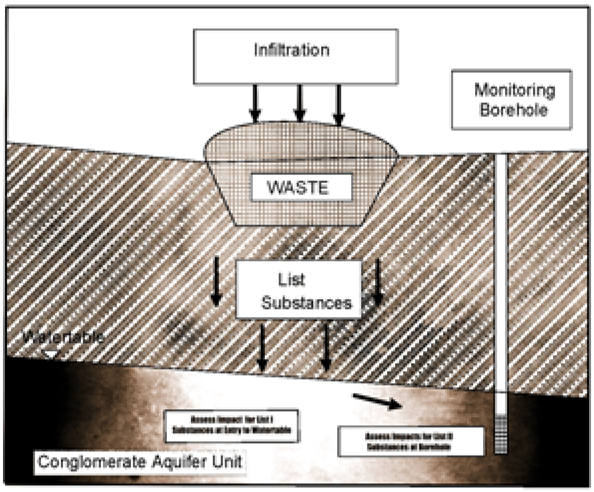


Fig. 3. Hydrogeological conceptual site model

The landfill is underlain by strata that are classified as Minor Aquifer by the Romanian Environment Agency and consists of inter-bedded clays, silts and sands. Hydraulic continuity is assumed between the sandstone horizons and is assumed to have a saturated aquifer hydraulic conductivity between 1.0 e-5 m/s and 3.4 e-6 m/s. The regional hydraulic gradient is 0.05 towards the SSE, to Jiul de Vest river.

The winter watertable lies at an average of 5 m below the site, and effective rainfall is estimated at approximately 692.8 mm/ year based on Meteo Parang Weather Station.

The potential source of pollution is contaminants within landfill leachate. The concentration of contaminants within leachate is dependent upon the waste type and will decline over time due to degradation of compounds, dilution by infiltrating water and losses to the vapour phase; therefore, existing leachate chemistry from other landfills was considered for this exercise. The environmental receptors considered are the groundwater body below the site within the bedrock and sand and silts for the List I substances, and an imaginary borehole immediately down-gradient of the site for the List II substances and non-listed substances.

Contaminants could reach the receptors via several pathways which comprise some different media components, transport mechanisms and attenuation processes:

Table 2. Pathways, transport and attenuation mechanisms

Media Component	Pollutant Transport Method	Attenuation Processes
HDPE Liner	Direct leakage through damage or defects or as a result of degradation of the liner	Declining source term. Dilution of leachate by rainwater infiltrating waste. Degradation of contaminants within leachate.
Mineral Liner (vertical pathway)	Advection and/ or Diffusion	Retardation, Dispersion

Inter-bedded clays, silts and sands (vertical pathway)	Advection and/ or Diffusion	Retardation, Dispersion
Aquifer Unit (Horizontal pathway/ saturated zone)	Advection and/ or Diffusion	Retardation, Dispersion

A QHRA has been undertaken using the following approaches:

- Analytical Solutions based on Domenico & Schwartz equation;
- A probabilistic method using Monte Carlo Simulations (LandSim);

Both advection and diffusion are possible contaminant migration mechanisms throughout the lifecycle of the landfill. The dominant mechanisms depend on the relationship between leachate levels and external hydraulic heads within the in situ inter-bedded clays, silts and sands and the underlying aquifer unit.

Domenico & Schwartz analytical solution has been used to predict concentrations of the priority contaminants (List I – Trichloroethene) at their respective compliance points, through the process of diffusion when leachate heads are below groundwater levels (winter watertable) in the surrounding subsoils – Scenario 1. A Conceptual Site Model and the landfill layout is presented in Fig. 4.

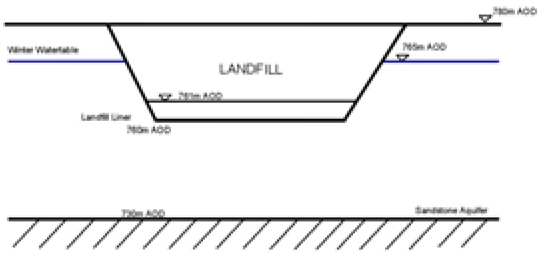


Fig. 4. Conceptual site model for Scenario 1 – winter watertable above leachate level

The input parameters used for the model are based on site-specific data when available and had been selected to be conservative. Domenico & Schwartz equation was used for the Scenario 1, and the solutions are derived in the Laplace Transform and was implemented into an Excel spreadsheet.

LandSim is used to predict leachate concentrations and elevations during the operational phase of the site and to estimate advective fluxes from the landfill when leachate heads exceed groundwater level (summer) in the surrounding inter-bedded subsoils and the potentiometric surface in the aquifer unit – Scenario 2 (engineered barrier without HDPE) and Scenario 3 (engineered barrier with HDPE) - Fig. 9.

Uncertainty within the selection of input parameters is addressed by the use of a probabilistic approach which allows the input parameters to be entered as ranges. The results are also returned as ranges and defined according to the probability of occurrence. The 95th percentile values are used as outputs from the model, which are representative of the reasonable worst-case performance of the landfill. The LandSim assessment models the performance of the landfill under normal conditions, i.e. it assumes that the engineering performance as designed throughout the operational life of the site.

5. RISK ASSESSMENT RESULTS

The models predict the concentration of the priority contaminants at both the List I (TCE – trichloroethene) and List II (Ammonium) compliance points as appropriate.

The compliance point for List I substances is at the base of the vertical pathway.

The compliance point for List II substances is 100 m downgradient of the edge of the waste within the application boundary.

The 95th percentile (worst case) concentrations are reported for each of the modelled Scenarios. Scenario 2 & 3 and have been compared to the Guideline Concentrations.

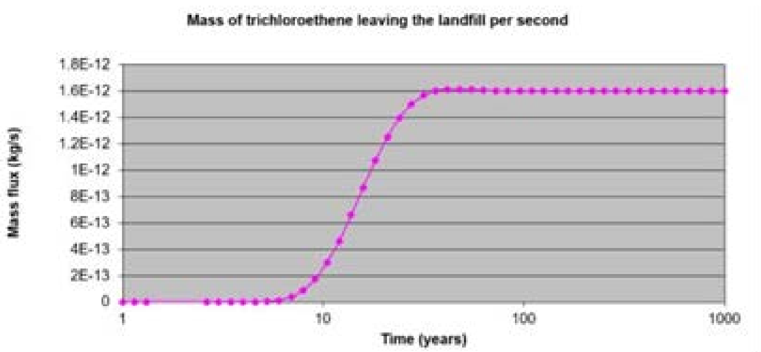
The results for both analytical and probabilistic approaches are presented separately below:

5.1. Analytical Solutions - Scenario 1

For Trichloroethene (TCE), which is a List I organic contaminant, we have used an Excel spreadsheet which solves Domenico & Schwartz equation. The engineered barriers liner consisted of a 1 m of compacted clay and HDPE geomembrane.

Based on the chemical analysis of similar leachate, an initial concentration of TCE was considered in this analysis. The compliance point for the risk assessment is set at entry to watertable, which is, in this case, the external edge of the liner. Using EU/ Romanian Drinking Water Standards (Groundwater Directive), a target concentration for TCE should be set, which is 10 µg/ l = 1×10^{-4}mg/ l. Therefore, TCE concentration at any time should not exceed target values.

Evaluation of mass of TCE leaving the landfill is shown in Fig. 5a and concentration of TCE at compliance point in Fig. 5b – maximum concentration is 2.46424×10^{-5}mg/ l which is lower than the target concentration of 1×10^{-4}mg/ l. Therefore there is an acceptable risk.



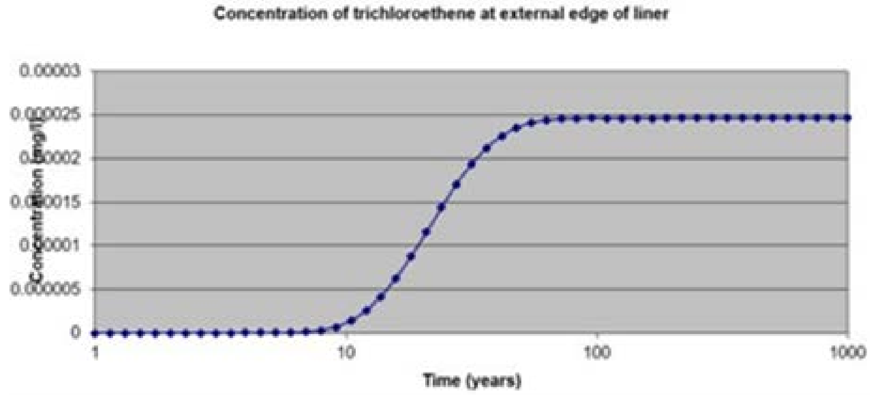


Fig. 5. (a) Scenario 1 – Mass of TCE leaving the landfill per second; (b) Scenario 1 – Concentration of TCE at the compliance point

5.2. Probabilistic Modelling - Scenario 2 & 3

To perform a probabilistic HRA, we have used LandSim software, a tool developed for UK Environment Agency by Golder. Both, Scenario 2 & 3 were modelled simultaneously in LandSim as Phase 1, respective Phase 2.

A graphic representation of the setup is presented in Fig. 6a. The results from the LandSim model are summarized in Fig. 6b – 7, for an ammonium concentration (List II substances) of 723 mg/ l (LogTriangular distribution (4.37, 723, 3640) for which the trigger level is 0.5 mg/ l.

From Fig. 6b – Scenario 2 for an engineered barrier without HDPE, it results that concentration at the external edge of the liner is higher than the trigger level and this value is halved at the compliance point but still higher than 0.5 mg/ l.

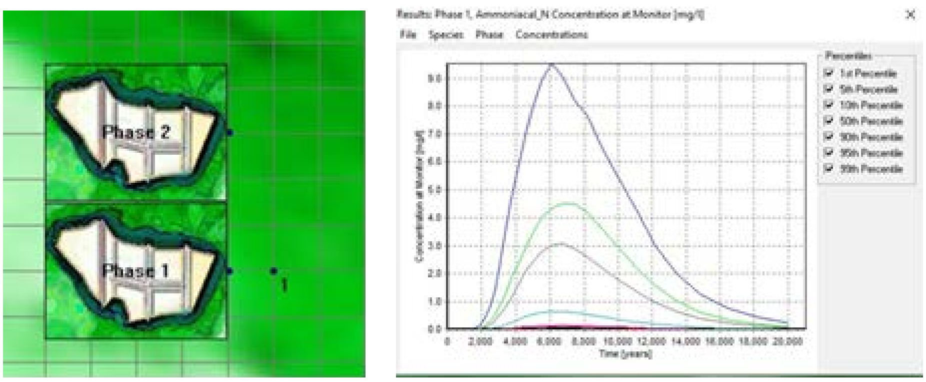


Fig. 6. (a) Scenario 2 (Phase 1) and Scenario 3 (Phase 2) for probabilistic risk assessment in LandSim; (b) Scenario 2 – Ammoniacal concentration at the external edge of the liner 95th percentile (light green curve)

On the other hand, Scenario 3 for an engineered barrier with HDOE, shows a value of 0.6 mg/ l of Ammoniacal_N which is slightly higher than the trigger value.

At the compliance point, the Ammoniacal_N concentration should be lower than the EAL (Environmental Assessment Limit) due to retardation, biodegradation, diffusion, and dispersion.

As a conclusion, only an experienced barrier with HDPE will be compliant with Groundwater Directive requirements for the proposed landfill.

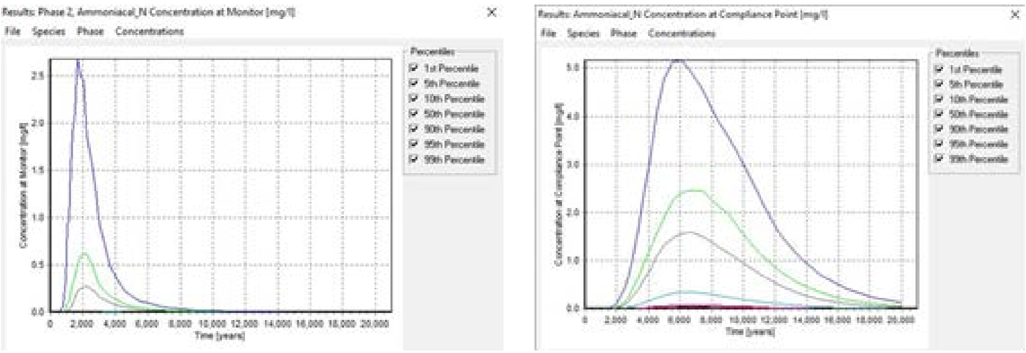


Fig. 7. (a) Scenario 3 – Ammoniacal concentration at the external edge of the liner 95th percentile (light green curve); (b) Scenario 2 & 3 – Ammoniacal concentration at compliance point 95th percentile (light green curve)

6. CONCLUSIONS

Due to the likely presence of substances from List I and II in the leachate, the VOC landfill has been engineered to include a leachate drainage and collection system as required by the Landfill Directive for non-hazardous landfills.

The results of the Risk Assessments show that List I substances in leachate are prevented from discharging directly to groundwater beneath the site. The results of the risk assessment for List II substances in leachate have shown that the landfill design prevents pollution of groundwater beneath the site from these substances for Scenario 3: Engineered Barrier with HDPE. Requisite surveillance in the form of risk-based leachate and groundwater monitoring will be carried out at the site, as part of Romanian Environmental Monitoring Plan.

Both conservative (analytical) and probabilistic risk assessments have shown that the landfill will not present a risk to groundwater and does not contravene the requirements of the Landfill/ Groundwater Directive.

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DESIGN OF LEACHATE COLLECTION SYSTEM USING MONTE CARLO SIMULATION

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Abstract: All landfills must have at their base a leachate drainage layer consisting of sands and gravels and/ or geosynthetic drainage material. The most important requirement for a Municipal Solid Waste (MSW) Landfill is that the leachate collection system has adequate drainage capacity to handle the maximum leachate flow produced during landfill operations. The authors present in the paper a comparison of few calculation methods for the design of leachate collection systems using a probabilistic approach, so these systems are compliant with the current legislation.

Keywords: *leachate, landfills; drainage layer; probabilistic approach; Monte Carlo simulation*

1. INTRODUCTION

The leachate drainage layer has a minimum thickness of 0.5 m as the Landfill Directive stipulates it (1999/31/EC); moreover, the leachate head builds up must be less than this thickness. To properly design a leachate drainage system for a landfill liner, we must be able to estimate the maximum saturated depth over the barrier for any proposed configuration. Landfill Directive, as well as National Regulations, limit the maximum leachate head over the liner to 0.5 m for MSW Landfills.

Factors affecting this maximum saturated depth include the inflow rate into the drainage layer, the hydraulic conductivity of the leachate drainage layer, the leachate flow distance from the upstream boundary to the leachate collection pipe, the slope of the landfill bottom liner, and the hydraulic condition at the downstream end of the drainage layer. Calculation of the liquid head over the barriers is based on the maximum inflow rate using a steady-state assumption, making the design conservative.

Few methods are currently used to calculate the maximum leachate head over the landfill liner, two of them proposed by Moore and two by Giroud et al. and McEnroe, respectively. To take into account the variability of inflow rate, hydraulic conductivity

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and horizontal drainage distance between the drainage pipes, to the maximum liquid head over the barrier, we have used Monte Carlo simulations using @RISK software. Input parameters are described by Probability Density Functions (PDFs) instead of unique values – as used in a deterministic design.

2. PROBABILITY DISTRIBUTION FUNCTIONS FOR INPUT PARAMETERS

Parameters which affect the maximum leachate head present in the drainage layer are:

- Horizontal drainage distance, L;
- Leachate inflow rate, r;
- Hydraulic conductivity of the drainage layer, k;
- Slope angle of the drainage layer, alpha.

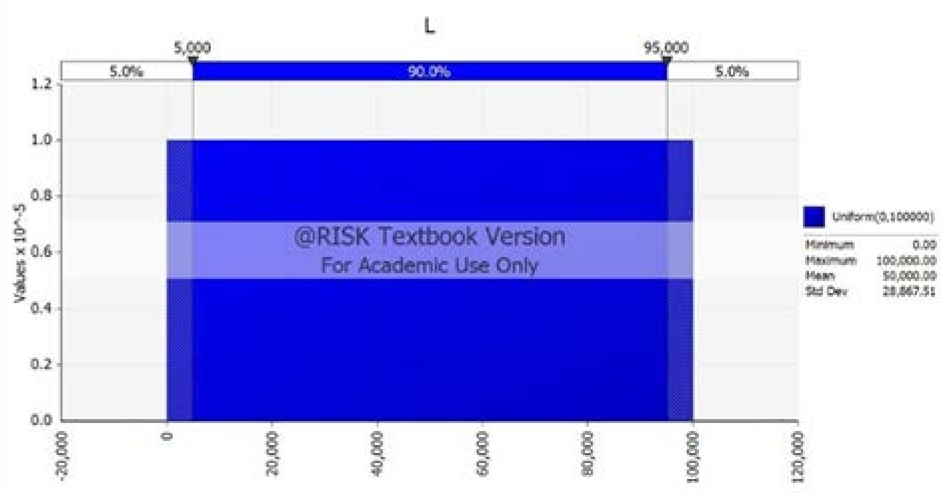
To run a stochastic analysis, first, we have to define these parameters as distribution functions.

Based on international practice, experience and regulations, the following distributions were used for the Monte Carlo simulation:

- L – uniform distribution: Fig. 1a;
- r – normal distribution: Fig. 2b;
- k – uniform distribution: Fig. 2a;
- alpha – triangular distribution: Fig. 2b

For the consistency of the units, we have used mm, sec, and mm/ sec.

To run Monte Carlo simulations, we have used @RISC software from Palisade – an add-in to Excel.



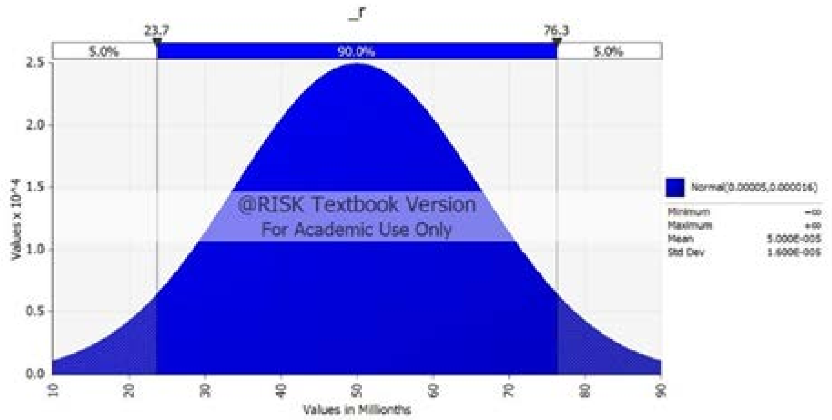


Fig. 1. (a) Uniform distribution for horizontal drainage system;
(b) Normal distribution for inflow rate

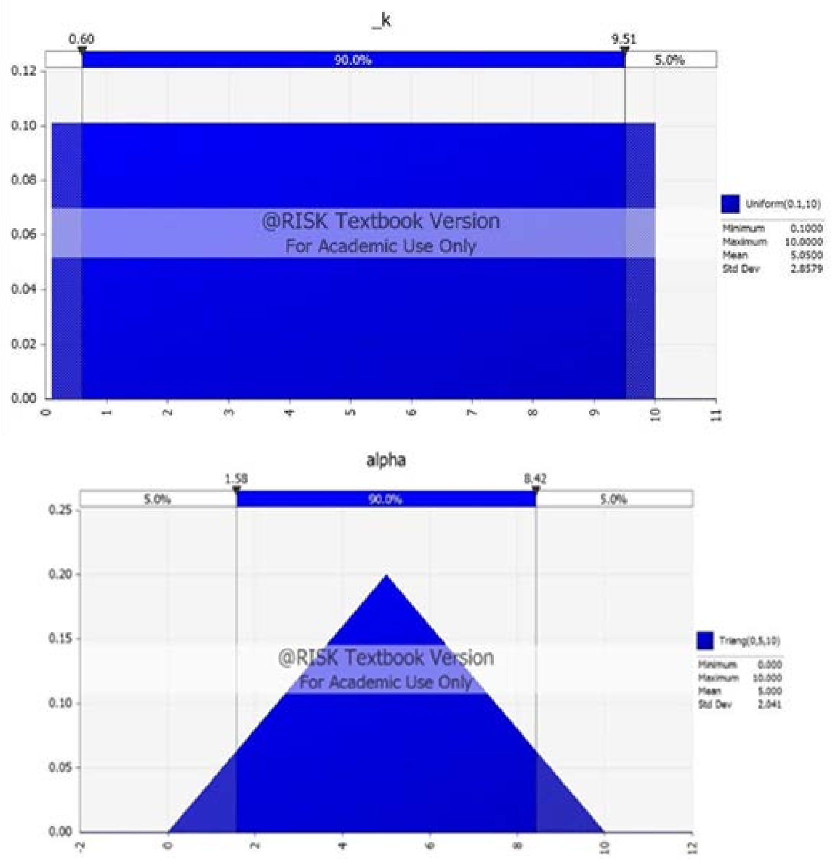


Fig. 2. (a) Uniform distribution of hydraulic conductivity;
(b) Triangular distribution for slope angle

3. MAXIMUM LEACHATE HEAD BY MONTE CARLO SIMULATIONS

During the landfill design, there are specific requirements regarding the estimation of the maximum liquid head over a barrier, which must always be assessed in two different locations. One of the requirements is to calculate the maximum leachate head over the base of the landfill, and this should not exceed 500 mm. Another requirement refers to the calculation of the maximum saturated depth in the cover system above the barrier and is essential to mention that this is one of the most important parameters which affects the stability of the final cover directly.

The following factors are known that affect the maximum saturated leachate drainage layer: the inflow rate into the drainage layer, the leachate flow distance from the upstream boundary to the leachate collection pipe, the slope of the landfill bottom liner and the hydraulic condition at the downstream and of the drainage layer.

In this paper, we will determine the maximum leachate head over the base of a landfill which is located in Jiu Valley and in order to simplify the calculation and still have relevant results, we will assume that the flow in the drainage layers of the leachate collection system is in a steady flow rate. In this case, the inflow rate will be constant and is assumed to be equal to the maximum inflow rate.

The are several methods to determine the maximum leachate head over a landfill liner; however, we will use for our particular case Moore's 1980 Method, Moore's 1983 Method and Giroud's 1992 Method.

3.1. Moore's 1980 Method

The maximum leachate head can be determined by the formula (1):

$$y_{max} = L \cdot \left(\frac{r}{k}\right)^{\frac{1}{2}} \left[\left(k \cdot \frac{S^2}{r}\right) + 1 \; - \left(k \cdot \frac{S}{r}\right) \left(S^2 + \frac{r}{k}\right)^{\frac{1}{2}} \right] \tag{1}$$

where:

y_{max} – maximum liquid head on the landfill barrier;

L – horizontal drainage distance, mm;

r – inflow rate (i.e. rate of vertical inflow to the drainage layer per unit horizontal area), mm/ sec

k – hydraulic conductivity of the drainage layer, mm/ sec;

S – slope of the drainage layer, S = tanα;

α – slope angle of drainage layer, measured from horizontal, degrees.

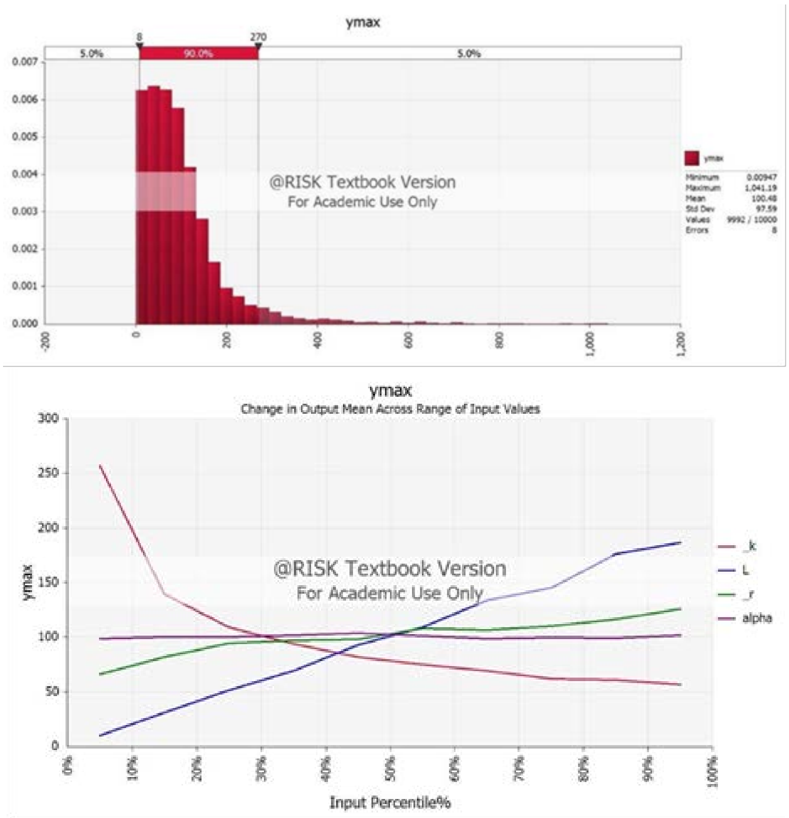


Fig. 3. (a) PDF Model Moore 80; (b) Spider graph Model Moore 80

For Model Moore 80 we ran a Monte Carlo simulation with 10000 realisations.

The resulting Probability Distribution Function is represented in Fig. 5, whereas Fig. 6 shows the influence of each input parameter to the final PDF.

3.2. Moore's 1983 Method

Moore presented formula (2) for estimating the maximum leachate head over a sloping barrier in 1983 and is a simpler version of the formula (1) presented in 1980.

$$y_{max} = L \cdot \left[\left(\frac{r}{k} + S^2 \right)^{1/2} - S \right] \quad (2)$$

where:

y_{max} – maximum liquid head on the landfill liner, mm;
L – horizontal drainage distance, mm;
r – inflow rate, mm/ sec;
k – hydraulic conductivity of the drainage layer, mm/ sec;

S – slope of the drainage layer, S = tanα;
α – slope angle of drainage layer, measured from horizontal, degrees.

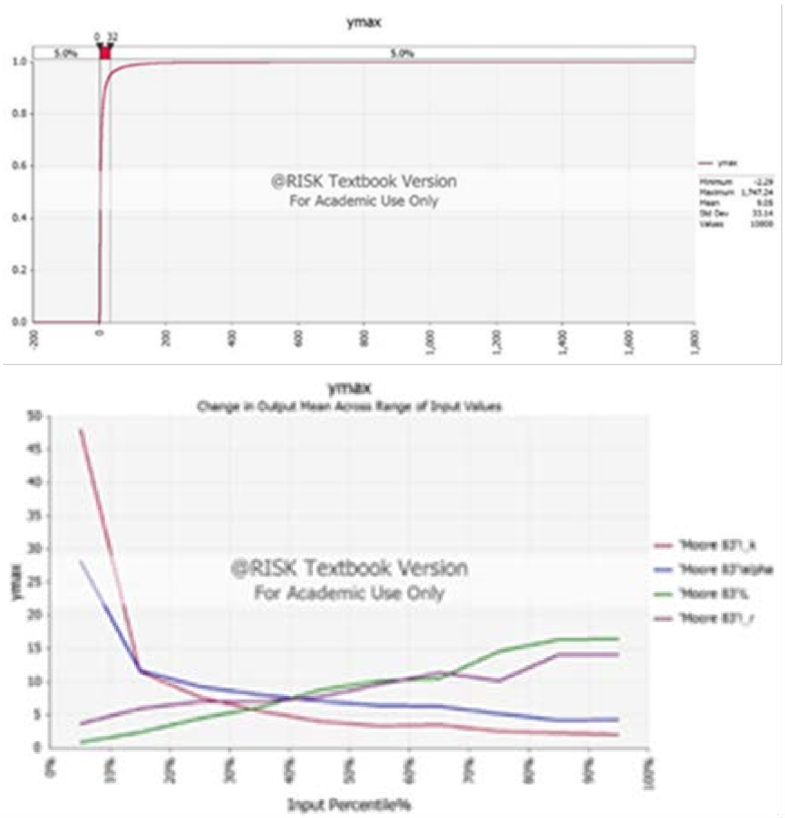


Fig. 4. (a) CDF Model Moore 83; (b) Spider graph Model Moore 83

The same number of realisations has been run for the Model Moore 83, and the Cumulative Distribution Function is shown in Fig. 4a.

The same spider graph – but for Model Moore 83 is presented in Fig. 4b.

This method is less conservative than its previous model.

3.3. Giroud's 1992 Method

A different formula (3) was presented by Giroud et al. for estimating the maximum leachate head over a sloping liner.

$$y_{max} = j \cdot L \cdot \frac{\left[\left(4 \cdot \frac{r}{k} + S^2\right)^{\frac{1}{2}} - S\right]}{(2 \cdot \cos \propto)} \quad (3)$$

The parameter j in the (3) can be calculated as:

$$j = 1 - 0.12 \cdot \exp\{-\left[log\left(1.6 \cdot \frac{\frac{r}{k}}{S^2}\right)^{\frac{5}{8}}\right]^2\} \tag{4}$$

where:

y_{max} – maximum liquid head on the landfill liner, mm;
L – horizontal drainage distance, mm;
r – inflow rate, mm/ sec;
k – hydraulic conductivity of the drainage layer, mm/ sec;
S – slope of the drainage layer, S = tanα;
α – slope angle of drainage layer, measured from horizontal, degrees.

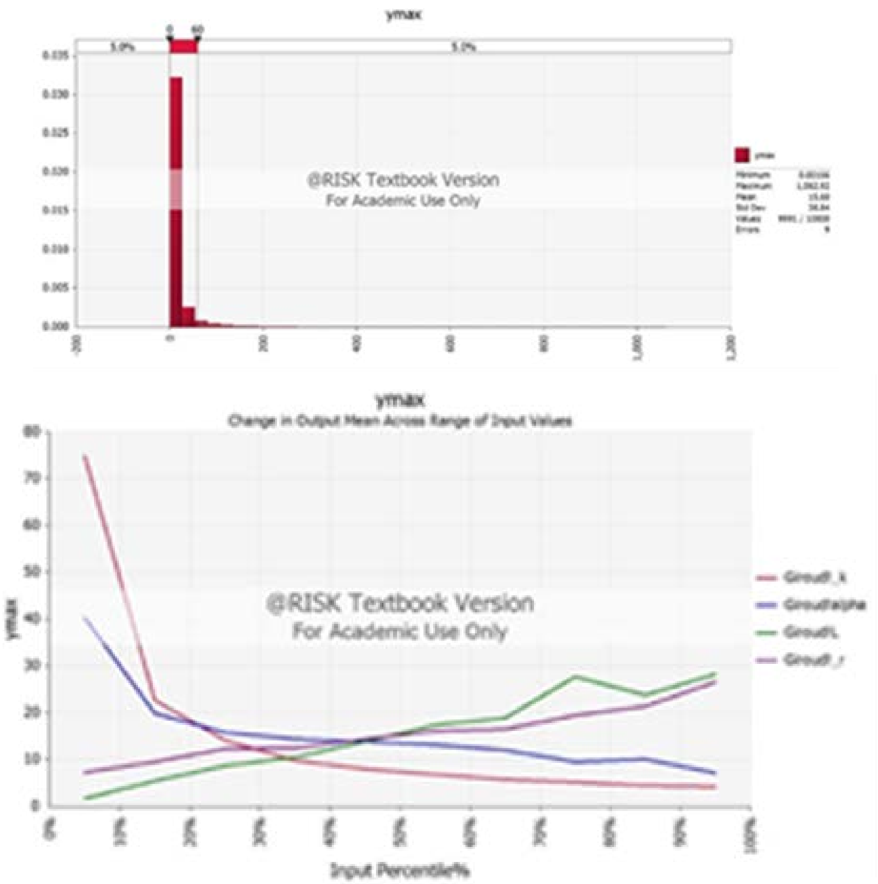


Fig. 5. (a) PDF Model Giroud; (b) Spider graph Model Giroud

Again, we ran a Monte Carlo simulation with 10000 realisations and results are similar to Model Moore 83.

Fig. 5a represents the resulting Probability Distribution Function, whereas Fig. 5b shows the change in output mean across a range of input values.

4. CONCLUSIONS

Simple Monte Carlo simulation – each of 10000 realisations, has been run for Moore 80, Moore 83 and Giroud models. The purpose for running a probabilistic analysis was to combine the input parameters – given as ranges and not as deterministic, unique values, and to see how each input parameter influences the final result, maximum leachate head within the drainage layer.

Input parameters are characterised by distribution functions which were derived based on international practice and their influence on the maximum leachate head is shown in spider graphs.

Simulation results are presented either as a Probability Distribution Function (PDF) or Cumulative Distribution Function (CDF), which can be used in the decision making process of the design of the leachate drainage system.

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DYNAMICS OF SPREAD OF FIRE-RELATED HARMFUL FACTORS IN METRO TUNNELS DURING A FORCED STOPPAGE OF THE METRO TRAIN

GIORGI NOZADZE [1]

Abstract: The present work deals with emergency situations which develop as a result of 30 MW-magnitude fires that may occur for various reasons within the metro (subway) tunnel infrastructure. The article will produce numerical modelling of the emergency situation within the PyroSim 2016 programme environment. It will offer a base model of the emergency situation for the following tunnel geometry: cross-sectional area of the tunnel – 20 m^2; length of the tunnel – 800 m; volumetric efficiency of the tunnel – 0,375; length of the metro train – 80 m; cross-sectional area of the train – 7.5 m^2. The article will explore the changing dynamics of the harmful factors (temperature, carbon monoxide, carbon dioxide and oxygen concentration levels) which develop in portals along the tunnel as a result of fires. The boundary conditions for various ventilation flows will be examined. We will study the effect of the location of the train and the fire on the dynamics of spread of harmful factors as a result of stoppage of the train inside the metro tunnel. The modelling process will determine the required time parameters for safe self-evacuation in an emergency situation. It can be used for the quick planning and implementation of emergency assistance activiti*es.*

Keywords: *Metro tunnel; fire, Hurmful factors; numerical modelling*

1. INTRODUCTION

Underground transport (metro) represents the fastest-growing transport network in global megalopolises. The metro has a history of approximately 150 years. The total length of underground metro networks across the world is 15, 000 km, of which 5,000 km have been constructed during the past 15 years. Existing networks are being expanded and reconstructed, while elsewhere, new subway transport centres are being established. Security of the underground transport system is particularly sensitive with regards to fire safety (Moraru et al, 2013; Moraru et al, 2017). This is primarily due to the shortage of evacuation options during fires in the metro, as well as the difficulty of the evacuation process scenario. Statistics of the main causes of fire in the metro (Long

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Poon and Richard Lau, 2007; Moraru and Babuţ, 2014) is presented in the form of a circle diagram (see Fig. 1).

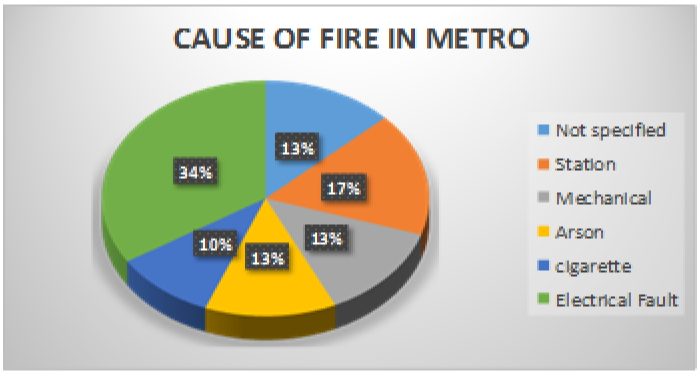

Fig. 1. Statistic data of the causes of fires in the metro

Based on the given statistics, approximately 17% of the metro fires occur at the stations and in areas adjacent to the stations, while the remaining 83% are accounted for by metro tunnels, where fire safety and evacuation activities are more difficult to implement than at the stations.

These instances usually lead to the stoppage of the metro train and the start of the self-evacuation process towards a free portal inside the tunnel.

During the last 30-35 years, there have been several cases of catastrophic fires occurring in the subway and funicular transportation systems. Although these were not particularly powerful fires, they all had disastrous results. For example, the Baku Metro fire in Azerbaijan killed 337 people in 1995, while 155 people died in Kaprun (Austria) in 2000, and 198 people in Daegu (South Korea) in 2003.

The aforementioned cases have all got several common characteristics: The materials involved in the fires were characterised by flammability and high toxicity of the substances released during the fire; The metro train was forced to come to halt inside the tunnel (Baku, Kaprun), or did not leave the station (Daegu);

The majority of the victims were poisoned by toxic gases.

- The complexity of the causes of fire.
- The absolute majority of metro systems use a high-voltage electrical power system. Statistics show Fig. 1. that electrical faults constitute the most common cause of fires today.

Fires in the metro can be subdivided into the following two categories:

- Fires in the metro’s power supply infrastructure;
- Fires in the metro’s metro train.

In present article we study fire in metro’s power supply infrastructure.

2. TASK OF NUMERICAL MODELLING

2.1. Initial Conditions

In the present study we do numerical modelling of possible fire scenarios in the metro's power supply system, using the tunnels of the Tbilisi metro as an example. The geometric data of the tunnel and the metro train is presented below:

- Length of the tunnel – L_t =800 m; cross-sectional area of the tunnel – S_t = 20 m^2; length of the train – L_{tr} = 80 m; cross-sectional area of the train – S_{tr} = 7.5 m^2; the location of the halted train is measured from the left-hand portal, using the coordinates $X_{tr\ 1}$ and $X_{tr.\ 2}$, whereby $X_{tr.\ 2} = X_{tr.\ 1} + L_{tr}$; fire location – X_F; location of the tunnel air shaft – X_S = 400 m from the left-hand portal; cross-sectional area of the shaft – S_i = 1, 4, 9 m^2; surface area of the burn – S_F; general formula for the burn reaction type – $C_xO_yH_zN_r$, the carbon compounds used in the high-molecular electric isolation material are modelled on the simple reaction of burning polyurethane, with the average carbon monoxide share of 0.2 g/g (Sean Thomas McKenna and Terence Richard Hull, 2016).The location of the halted train is measured from the left-hand portal, and the modelled cases are: $X_{tr\ 1}$ =202 m, 302 m, 351 m, 402 m, 502 m, 602 m. The fire source is located at the X_F = 700 m mark from the left-hand portal. The modelled cases are classified as follows, depending on the position with respect to the air shaft (see Fig.2.):

- $X_{tr\ 1}, X_{tr.\ 2} < X_S < X_F$; $X_{tr\ 1}$ =202 ∂., 302 ∂.
- $X_{tr\ 1} < X_S < X_{tr.\ 2} < X_F$; $X_{tr\ 1}$ =351 ∂., (1)
- $X_S < X_{tr.\ 1}, X_{tr.\ 2} < X_F$ $X_{tr\ 1}$ =402 ∂., 502 ∂, 602 ∂.

2.2. Boundary Conditions

The flow of heat from the fire and the boundary conditions for the ventilation flow are presented in Fig. 2.

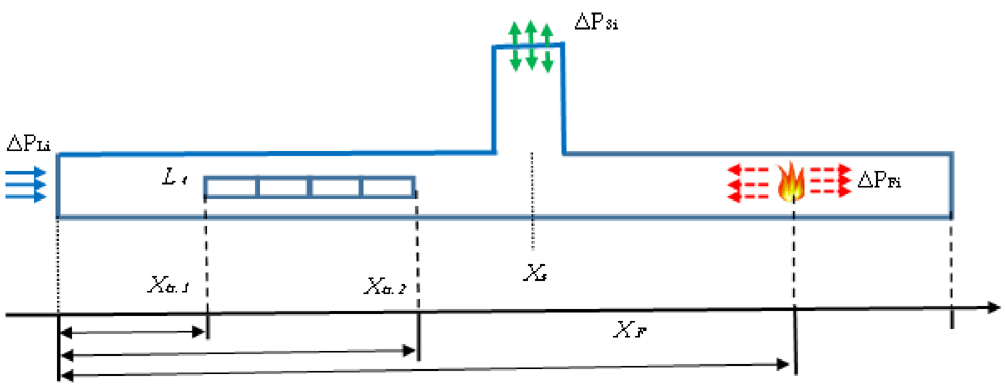

Fig. 2. An emergency situation model of a forced stop of a train during infrastructural fires in a subway tunnel

The dynamic pressure from the ventilation flow in the left-hand portal is modelled as the difference in pressure between the portals – ΔP_{Li} .

A numerical model was established within the set task. Numerical modelling was used to study the dynamics of spread of harmful factors from heat flow ΔP_{Fi} which stems from the fire. Boundary conditions created by additional dynamic flows at one of the portals and the outer cross-section of the intermediate air shaft inside the metro tunnel have also been examined – ΔP_{Li} = ±1, ± 10, ±100 Pa, ΔP_{Si} = ±1, ± 10, ±100 Pa. Numerical modelling time – 300 sec, 1200 sec, 2400 sec.

The effect of the location of the halted train on the dynamics of the harmful factors has been studied. In order to obtain quick and optimal results from multiparameter numerical modelling, we have introduced the 'base model concept,'(Ilias at all, 2017) which involves forming the worst possible starting and boundary conditions for the given geometric parameters of the tunnel, and obtaining the worst spatial scale and time scale for the harmful factors.

The harmful factors examined in the present study are the increase in carbon monoxide and carbon dioxide concentration levels, decrease in oxygen levels, as well as the dynamics of temperature distribution in the metro tunnel in case of a 30 MW-magnitude fire. For the correct formulation of the problem of the distribution of the temperature harmful factor, it will be necessary to consider the influence of the surrounding tunnel wall. This can be taken into account in the "base model" with the help of the technology proposed in the articles (Lancava, 1982,1985)

Detectors are located along the symmetric interface of the tunnel's cross section, at a height of Z=1.5 m from the tunnel bottom, at 100 m intervals.

Clearly, the worst possible situation applies to fires of the maximum strength required by technical regulations (30 MW), whereby the train is located at a short distance from the fire source (in our case, 602 m from the left-hand portal), and the cross section of the 10 m tall air shaft is minimal (1 m^2 in the case of our model). See Fig. 3

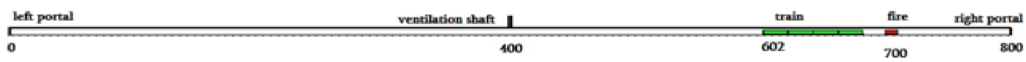

Fig. 3. The Geometry data of 'base model' of metro tunnel in Pyrosim software

Results of numerical modelling, displaying the dynamics of each harmful factor in time for the 'base model,' are shown below.

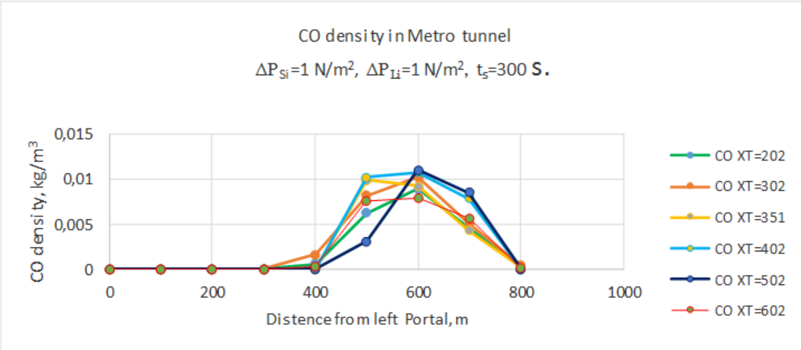

Fig. 4. Dependes of distribution of carbon monoxide concentration in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height Z = 1.5 along the tunnel, simulation time 300 seconds)

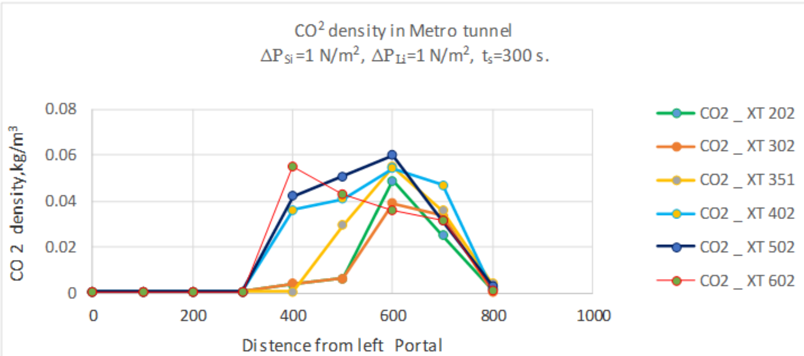

Fig. 5. Dependes of distribution of carbon dioxide concentration in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height Z = 1.5 along the tunnel, simulation time 300 seconds)

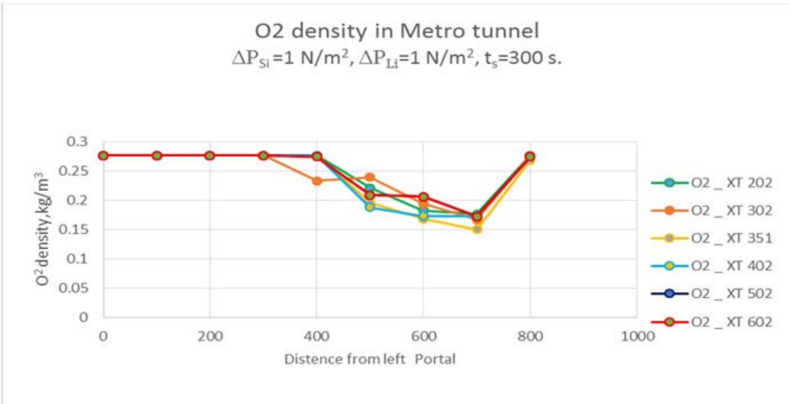

Fig. 6. Dependes of distribution of oxigen concentration in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height Z = 1.5 along the tunnel, simulation time 300 seconds)

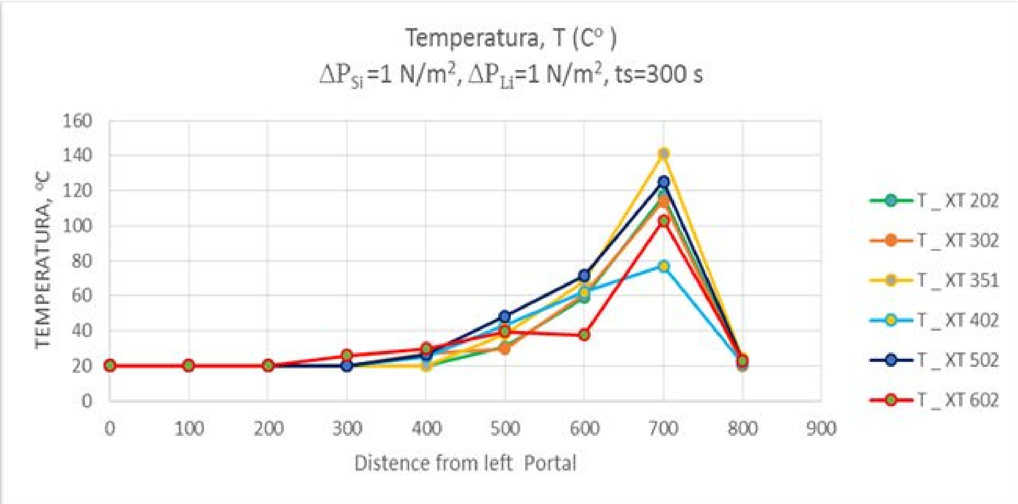

Fig. 7. Dependes of distribution of Temperature in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height Z = 1.5 along the tunnel, simulation time 300 seconds)

We examine a situation where the metro tunnel ventilation system becomes disabled, which is modelled on the boundary conditions for the 'base model' – through the total minimal increase of the natural dynamic pressure on one of the portals ($\Delta P_{Li} = \pm 1$ n/m^2), and the total dynamic pressure increase on the outer cross section of the air shaft ($\Delta P_{Si} = \pm 1$ n/m^2)For the Basic model, the process of changing the spatial scale of the harmful factors along the tunnel was studed. time of modeling t = 300 s, 1200 s, 2400 s.The results presented on the Fig. 9-12

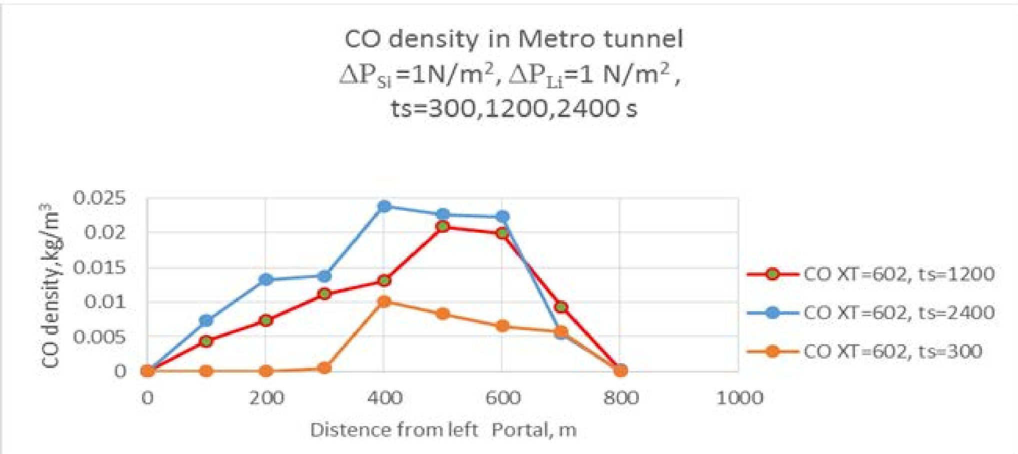

Fig. 8. Dynamics of changes the spatial scale of concentration increase of carbon monoxide along the tunnel. The simulation time is ts = 300 s, 1200 s, 2400 sec.

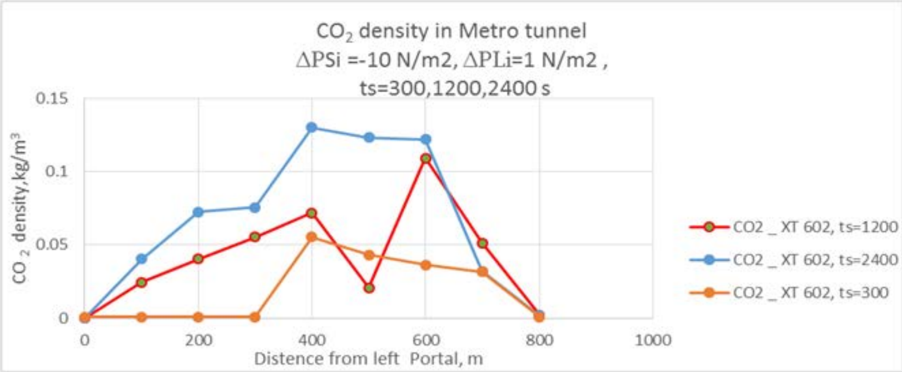

Fig. 9. Dynamics of changes the spatial scale of concentration increase of carbon dioxide along the tunnel. The simulation time is ts = 300 s, 1200 s, 2400 sec.

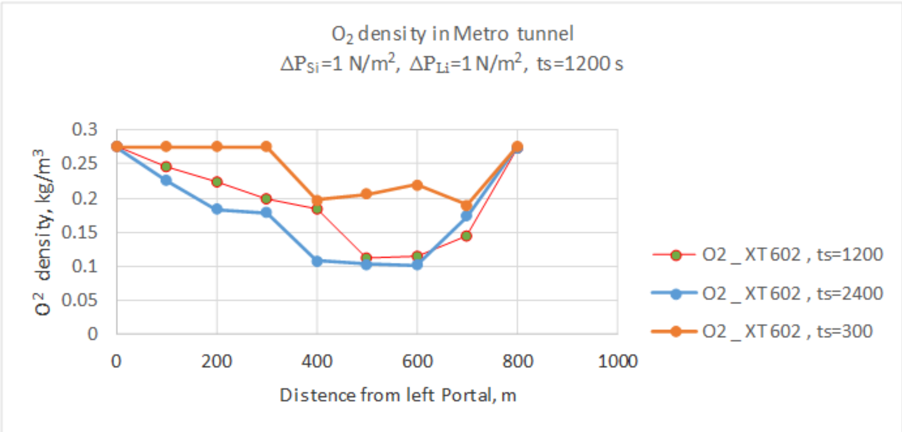

Fig. 10. Dynamics of changes the spatial scale of concentration decrease of Oxygen along the tunnel. The simulation time is ts = 300 s, 1200 s, 2400 sec.

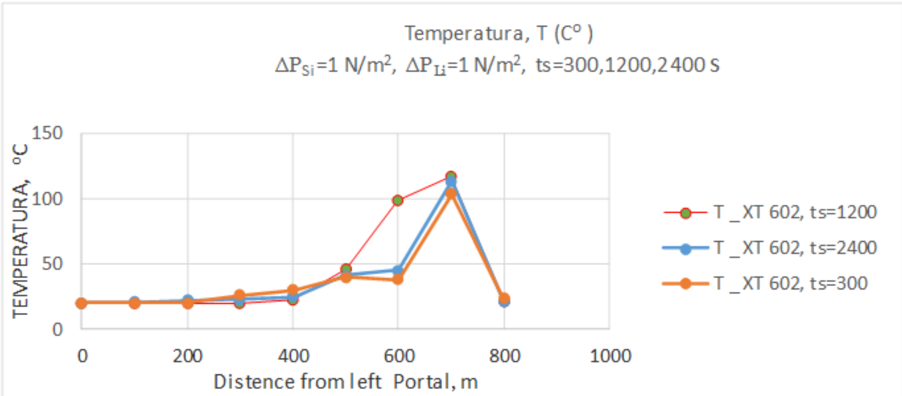

Fig. 11. Dynamics of changes the spatial scale of Temperature along the tunnel. The simulation time is ts = 300 s, 1200 s, 2400 sec.

RESULTS

Results of the numerical experiments allow us to produce a practical assessment of spatial and time distribution of the harmful factors during the realisation of various boundary conditions. The test quantity of toxic and/or asphyxiants gases is their concentration level in the tunnel space, while the thermal harmful factor is represented by the average gas temperature along the tunnel.

- The modelling of the emergency situation caused by fire inside the metro tunnel is carried out on the basis of the ‘base model,’ which accounts for the numerical realisation of the worst possible scenario of creation and spread of harmful factors based on the existing tunnel geometry, as well as initial and boundary conditions;
- It is shown that the dynamics of spread of harmful factors are not significantly affected by the location of the halted train, when the volumetric efficiency of the tunnel’s cross section is α=0,375.;
- In case of 30 MW-magnitude fires, the spread of toxic and asphyxiant gases occurs over almost 300 m in 5 minutes, under the boundary and initial conditions that are realizd in the base model. The spatial scale of these factors is characterised by a tendency of growth.
- The danger zone of the temperature factor is quickly stabilised. Its spatial boundary is located within a distance of 100-150 m from the fire source, on both sides of the tunnel.

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STATISTICAL ANALYSIS OF ENDOGENOUS FIRES AND SELF-HEATING PHENOMENA OCCURRED BETWEEN 1997 ÷ 2017 IN JIU VALLEY COAL MINES

MARIUS ROMAN ROGOBETE [1]

Abstract: *The coal self-heating phenomena in mines are the main events, which uncontrolled and un-fought against, cause loss of useful substances, materials and even human lives. In order to counteract the effects of these phenomena, their statistical study helps to identify the risks of spontaneous combustion in case of applying different exploitation methods in certain mining conditions, and by applying specific control measures these risks can be diminished.*

Keywords: *self-heating, coal, fire, spontaneous combustion*

1. INTRODUCTION

In order to study coal self-heating phenomena, it is necessary to establish basic theoretical notions regarding mine fires, so that these phenomena can be analysed from several points of view, taking into account all the factors that influence the occurrence and the development of spontaneous combustions.

1.1. Definitions

„Mine fires”:

1. Fires occurring in underground mining or quarries and mining operations from the surface which jeopardize workers' safety and the continuity of the production process in underground mining [18];
2. Any fire that arises in the mine, as well as those fires from the surface whose gaseous combustion products reach the mine together with the ventilation stream or the fires propagating from the surface towards the mining works [5];
3. The fires that occur in the underground works of a mine, as a result of self-inflammation of coal, of an explosion or other accidental causes [2].

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„Spontaneous combustion”

1. Self-combustion of coal at low velocities without heat input from the outside [20].
2. Phenomenon resulting from the heating of coal by slow oxidation, which can only occur through the passage of air through cracks present in the massif [12].
3. The phenomenon which arises when, by the reaction of low temperature between coal and oxygen, the heat is not adequately dissipated by conduction or convection, resulting in a net increase in the temperature in the coal mass [15].

„Burning”

1. A rapid oxidation reaction of a substance, usually in the presence of oxygen in the atmosphere, with heat development and generally accompanied by light [4].
2. An exothermic reaction of a combustible substance with a comburant, generally accompanied by flames and / or incandescence and / or smoke emission [22].

„Burning temperature”

The minimum temperature at which a solid or liquid fuel burns to exhaustion [7].

„Burning velocity”

The amount of fuel consumed by combustion in the unit of time [7].

„Ignition”

Initiation of combustion occurs when the combustible substance comes into contact with an external source of ignition in the presence of oxygen in the air, or internal, due to the internal generation of heat [21].

1.2. Classification of underground fires

Classification of underground fires is quite diverse, from one country to another or even researchers from the same country have come up with different approaches, as follows:

In the US, statistically, fires are open (if seen) or hidden (in closed areas);

In Germany, all fires are considered endogenous except open fires;

In France the spontaneous combustion fires are mine fires, all the others are considered as fires [16].

Several classifications were used in the UK [13], such as that made by Holding in 1981 – fires caused by spontaneous combustions and fires generated by other causes, Thorp (1981) - open fires and fires caused by spontaneous combustion or Morris (1984) - natural fires caused by spontaneous combustion and fires caused by man by direct or indirect action (electricity, conveyor belts or other equipment, combustion and welding, fuels, explosives, etc.);

In Russia and the Ex-Soviet area fires are considered endogenous because of self-ignition, and from other causes they are considered exogenous [17];

In Romania, due to the Soviet influence, the classification in endogenous fires and exogenous fires is used [11].

Endogenous fires are considered those fires that occur as a result of the self-ignition of the useful mineral substance (spontaneous combustion).

Exogenous fires (or underground fires) are considered those fires that are due to external factors.

It should be noted that endogenous fires can generate exogenous fires in conditions where fires from the massif ignites bandages, machinery, support etc., as well as exogenous fires can produce endogenous fires by increasing the temperature of the coal in the massif, triggering the self-heating phenomenon.

1.3. Coal oxidation

The coal oxidation phenomenon represents its reaction with atmospheric oxygen, resulting mainly in products such as CO_2, CO, H_2O, but also other gases whose content depends on the temperature at which the oxidation takes place, on the properties of the coal as well as on the intervention of other factors in the process.

During oxidation, the oxidation rate is a function of temperature and can double at 10°C increase in the temperature of the coal. The rate of temperature increase depends on the speed of heat dissipation – by increasing the temperature, increases the rate of oxidation, which produces more heat, thus the process is self-accelerating [14].

In order to prevent the oxidation of coal at low temperatures from turning into heating, it must be in one of the following steady states:

The amount of circulating air is small, therefore the amount of oxygen is small resulting in a reduced oxidation rate, obtaining an equilibrium state in which heat is dissipated as quickly as it is generated;

If the amount of air circulating is large, the cooling effect may be so high as to prevent significant temperature rise, limiting the oxidation rate.

In the interim situation, when the oxygen supply rate and the heat dissipation rate are between the two equilibrium states and there is sufficient mass of coal, there is the premise that the oxidation accelerates, the phenomenon being accompanied by temperature rise, and if the process is not interrupted the spontaneous combustion and then the fire occur.

1.4. Elements involved in the occurrence of fires

The elements required for the occurrence of fires are three (Fig.1).

The mining works from Jiu Valley coal mines contain all three elements.

Fuel - is represented by different organic materials (wood, liquid fuels, oils, etc.) but especially coal;

The oxidant environment – required for the occurrence and maintenance of the spontaneous combustion is the oxygen in the air that circulates through both the current mining works, and in the goaf and fissures from the coal massif. In Romania, oxygen content in mine air is regulated by specific occupational safety standards and cannot be less than 19% volume [19].

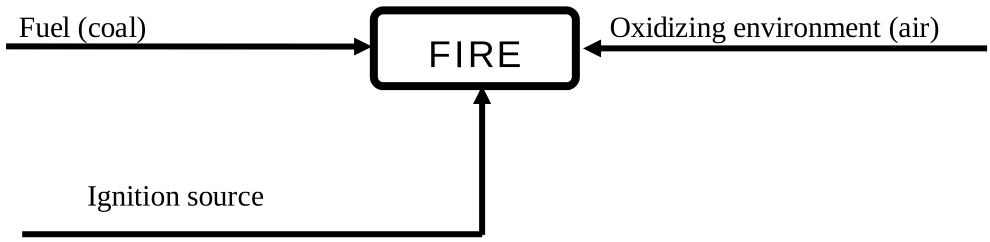

Fig.1. The necessary elements of fire occurrence

In underground there are the following forms of oxidation:

Slow oxidation (rotting) occurs in the presence of excess oxygen and, as a result, the complete decomposition of organic matter is observed, with the direct participation of microorganisms (bacteria, fungi);

The actual oxidation (burning) which causes local heating due to the combination of molecules of the substance with the oxygen molecules, as result the substance ignites and begins to burn. Heat produced by this combustion heats the closest layer of the substance, and if the fuel reaches a certain temperature, it ignites and in its turn produces heat. In this way the reaction can continue until the complete burning of the substance. This process can be interrupted only if the heating of the still ungrounded substance is stopped when the temperature of the combustible material is below the combustion temperature;

Chemical disaggregation is an oxidation process that takes place in a material under the influence of air and aqueous solutions, producing major changes in the chemical composition of the matter [12].

Ignition source - must provide a quantity of heat that generates a temperature which exceeds the ignition limit of the fuel. In case of endogenous flames, heat comes from the oxidation of fuel (coal) due to specific conditions, and after oxidation it is self-heating up to the combustion temperature.

In the absence of any of the mentioned elements, the fire cannot occur, and if there is already a fire, by removing one of the three elements, the fire is extinguished.

1.5. Factors that favour the occurrence of spontaneous combustions

Factors favouring the occurrence of spontaneous combustion are divided into two major categories: objective and subjective [1; 2; 3].

Objective factors

They comprise all the elements which lead to self-ignition and which come from the nature of the deposit, being independent of human activity. These factors cannot lead to the occurrence of fires without the participation of the conditions of the technological process, namely the subjective factors.

Objective factors highlight the coal self-ignition tendency from the physico-chemical, petrographic and geologic point of view.

a) *Physico-chemical factors* –refer to the physical or chemical characteristics that determine the behaviour of coal in the oxidation process.

b) Petrographic factors. Petrographic research on coal composition with varying degrees of metamorphism and self-ignition tendencies has shown that once with the increase of fusith content and decrease in vitreous content, the self-ignition tendency also increases.

c) Geologic nature factors are determined by geologic factors that intervene differently in the self-ignition process.

Subjective factors

These factors create the necessary conditions for self-ignition and are related to human activity in the underground and are more important than the objective factors in the spontaneous combustion occurrence.

A classification of subjective factors can be:

a) Generated form exploitation
b) Generated from the digging, support and maintenance of workings
c) Ventilation dependent
d) Generated form exploitation

Factors contributing to the occurrence of coal self-ignition phenomena have been structured by French and Belgian researchers as shown in Figure 2.

1.6. Location of self-ignition phenomena

As a result of the analyses, it was found that the places where endogenous fires occur are divided into three categories:

a) Fires occurred in the goaf.
b) Fires occurred in the fissured massif.
c) Fires from current mine workings.

1.7. Phenomena that accompanies spontaneous combustion

During the production of spontaneous combustions there are other phenomena that are directly related to the manner of manifestation of self-ignition, being able to endanger the normal activity and the safety of the workers.

Combustion gases are the product of the oxidation and dry coal distillation processes. Depending on the existence of different chemical elements in coal, these gases are mainly carbon dioxide - CO_2, carbon monoxide - CO, sulphur dioxide - SO_2, hydrogen sulphide - H_2S, hydrogen - H_2, saturated hydrocarbons (methane - CH_4 , ethane - C_2H_6, propane - C_3H_8, butane - C_4H_{10}), unsaturated hydrocarbons (ethylene - C_2H_4, acetylene - C_2H_2), these are accompanied by oxygen, water and coal dust.

The gases resulting from self-heating are: toxic - CO, SO_2, H_2S; asphyxiating - CO_2, saturated and unsaturated hydrocarbons; explosive - H_2, CO, H_2S, saturated and unsaturated hydrocarbons.

The **temperature of the combustion gases** is much higher than the one of the environment, so contact with them is another hazard that accompanies the spontaneous combustion phenomenon, in the fireplace the gas temperature being in the range 600÷800°C, at the contact with the walls of the mining works being cooled down while being removed from the fireplace, cooling down being also influenced by the mixture of these gases with fresh air.

Caloric depression produced by the spontaneous combustion. The occurrence of mine fires leads to the occurrence of an additional and high intensity aero-propulsion force in the ventilation system, a force which is called the caloric depression [2].

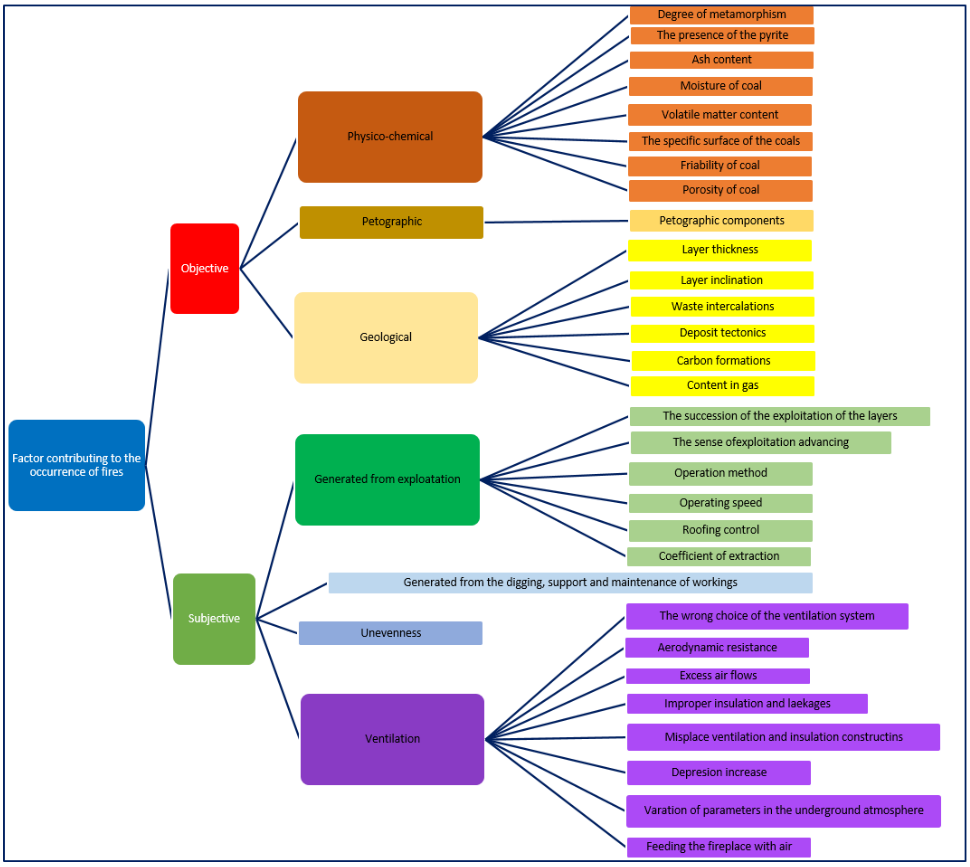

Fig. 2. Factors contributing to the occurrence of fires

1.8. Theories about the process of carbonization of coal self-ignition

Research on mine fires has led over time to the development of several theories about the coal self-ignition process, among which the best known and among the most popular among the specialists are [3]:

- The theory of the coal-oxygen complex;
- Pyritical theory;
- Biological catalysis;
- Phenolic theory;
- The theory of coal oxidation.

1.9. Mechanism of the self-ignition process (spontaneous combustion)

Self-ignition is a complex, physical, pysico-chemical coal oxidation process that takes place in three stages of successive or simultaneous development, which influence each other: self-heating; humidity evaporation; actual self-ignition [6; 8; 9; 10].

The three successive stages of spontaneous combustion development are shown in Figure 3.

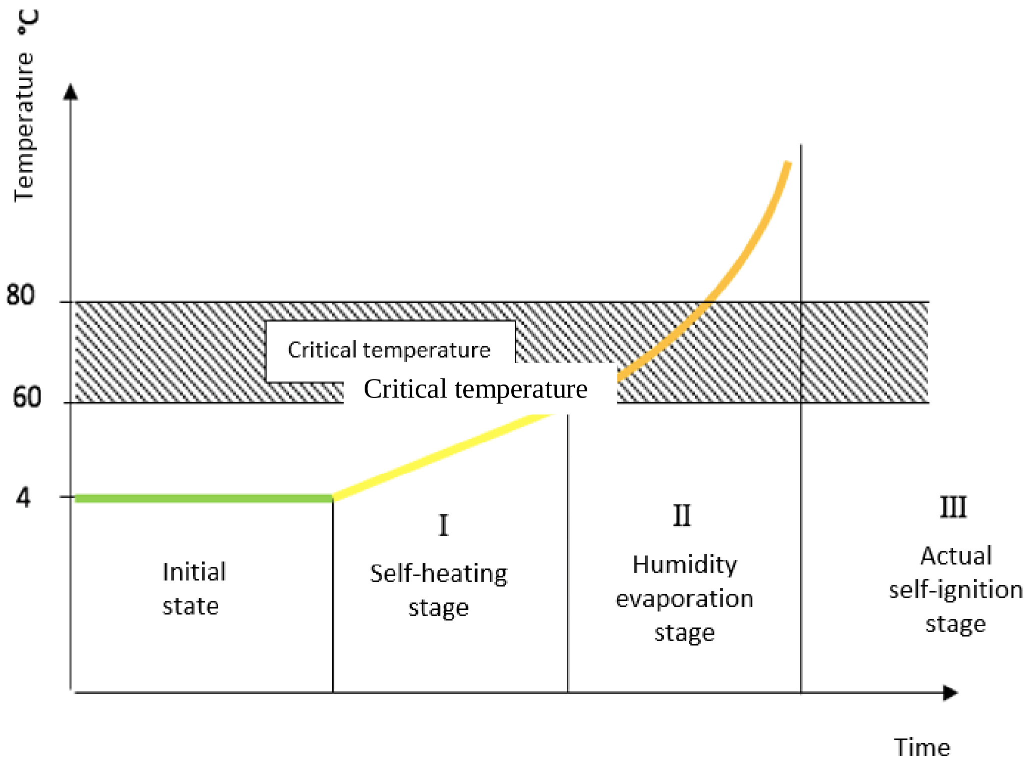

Fig. 3. Stages of spontaneous combustion phenomena development

2. STUDY OF THE CAUSES OF THE OCCURRENCE OF SELF-HEATING PHENOMENA

2.1. The general situation of the phenomena occurred during the analysed period [23]

During the period 1997 ÷ 2017, 125 phenomena related to the theme approached were identified, being taken into account all the 9 mines that operated at the beginning of the period, although only 6 of them are currently in operation

These 125 phenomena have been classified as follows:

Endogenous fires - 65 of which:

- 62 new fires
- 3 reactivations of endogenous fires

Self-heating phenomena (not reaching the burning point) - 55

- Methane ignition - 3
- Stuffing fires - 2

Table1. *Global situation of phenomena occurred during the period 1997÷2017*

Year \ Mining unit	Lonea	Petrila	Livezeni	Aninoasa	Vulcan	Paroşeni	Lupeni	Bărbăteni	Uricani	**TOTAL**
1997	2	0	1	1	2	0	0	2	0	**8**
1998	4	0	0	0	1	0	0	0	0	**5**
1999	0	0	0	0	0	1	0	0	0	**1**
2000	0	0	0	1	1	0	0	0	0	**2**
2001	1	0	0	1	1	0	0	1	1	**5**
2002	1	4	0	0	2	0	4	1	0	**12**
2003	2	2	4	1	2	0	2	0	0	**13**
2004	3	1	0	0	2	1	2	0	0	**9**
2005	2	1	2	0	0	0	1	1	0	**7**
2006	1	0	1	0	2	0	8	0	2	**14**
2007	1	0	1	0	0	0	1	0	0	**3**
2008	3	1	1	0	0	0	1	0	0	**6**
2009	0	0	0	0	1	0	3	0	0	**4**
2010	4	0	1	0	1	0	6	0	0	**12**
2011	0	2	3	0	1	0	1	0	0	**7**
2012	0	0	2	0	0	0	3	0	0	**5**
2013	1	0	0	0	0	0	2	0	0	**3**
2014	1	0	0	0	0	0	0	0	0	**1**
2015	0	0	0	0	1	0	1	0	0	**2**
2016	2	0	1	0	1	0	0	0	0	**4**
2017	2	0	0	0	0	0	0	0	0	**2**
TOTAL	**30**	**11**	**17**	**4**	**18**	**2**	**35**	**5**	**3**	**125**

It is observed that during the analysed period most phenomena occurred at Lupeni mining unit - 35, followed by Lonea mining unit with 30 phenomena (fig.4).

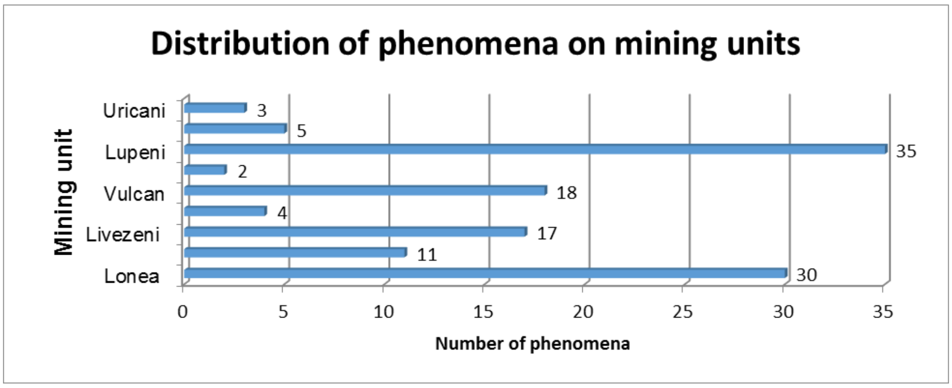

Fig. 4. Distribution of phenomena on mining units

Most phenomena in one year - 14, were in 2006, followed by 2003 with 13 phenomena and 2002, respectively 2010 with 12 phenomena (Fig.5).

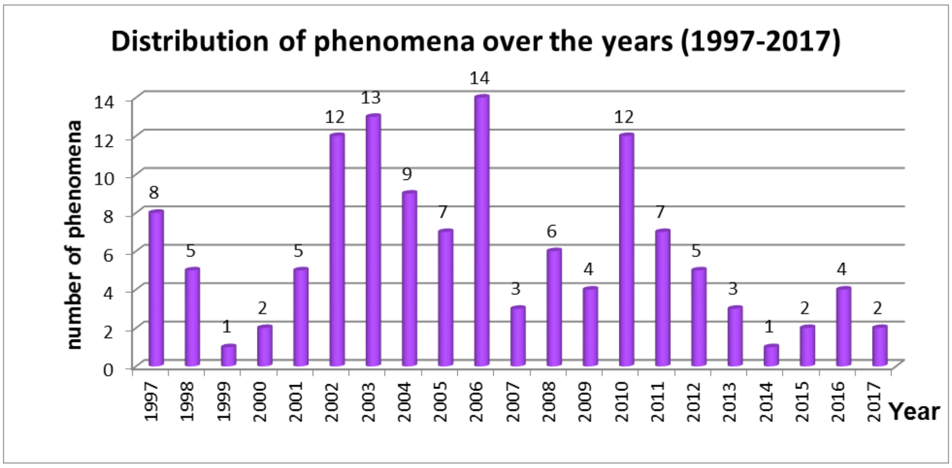

Fig. 5. Distribution of phenomena over the years

Most events related to coal self-heating in one year also took place at Lupeni mining unit, respectively 8 in 2006 and 6 in 2010.

2.2. The particular situation of the self-heating phenomena occurred during the analysed period

2.2.1. Situation over coal beds and blocks

► Lonea mining unit: all 30 phenomena occurred in coal bed 3, the distribution on blocks being the following:

- Block II – 5 phenomena;
- Block III – 13 phenomena;
- Block IV – 3 phenomena;
- Block VI – 2 phenomena;
- Block VII – 7 phenomena.

► Petrila mining unit: the 11 phenomena occurred in coal bed 3, in blocks II and 0 as follows:

- Block 0 – 3 phenomena;
- Block II – 8 phenomena.

► Livezeni mining unit: the 17 phenomena took place as follows:

- Bed no.13, Block IX - 2 phenomena;
- Bed no.3, Block VI – 15 phenomena.

► Aninoasa mining unit: the distribution of the 4 phenomena is as follows:

- Bed no.13, Block I – 1 phenomenon;
- Bed no. 5, Block II – 1 phenomenon;
- Bed no.3, Block II – 2 phenomena.

► Vulcan mining unit: all 18 phenomena took place in coal bed 3, the division by blocks being the following:

- Block II – 1 phenomenon;
- Block IV – 1 phenomenon;
- Block VI – 8 phenomena;
- Block VII – 5 phenomena;
- Block VIII – 3 phenomena.

► Paroșeni mining unit: The 2 phenomena took place as follows:

- Bed no.5, Block 0 – 1 phenomenon;
- Bed no.3, Block VI – 1 phenomenon.

► Lupeni mining unit: all 35 phenomena took place in coal bed 3, the distribution on the blocks being the following:

- Block II – 6 phenomena;
- Block III – 1 phenomenon;
- Block IV – 11 phenomena;
- Block II – 16 phenomena;
- Block IX – 1 phenomenon.

► Bărbăteni mining unit –all 5 phenomena took place in coal bed 3, block XI.

► Uricani mining unit –the 3 phenomena occurred as follows:

- Bed no.5, Block V – 1 phenomenon;
- Bed no.5, Block VI – 1 phenomenon;
- Bed no. 3, Block III – 1 phenomenon.

From the analysis of the phenomena that occurred during the period 1997 ÷ 2017 it results that 118 of them occurred in coal bed no. 3, representing 94.4% of the total phenomena, the remaining 7 phenomena being distributed: 4 phenomena (3.2%) in the coal bed no. 5, respectively 3 phenomena (2.4%) in coal bed no. 13.

2.2.2. Situation of phenomena depending on the thickness and inclination of the beds

Depending on the thickness of the coal beds, the 125 phenomena are distributed as follows:

- Thick coal beds (thickness greater than 4 m) – 118 phenomena;
- Average coal beds (thickness between 2.5 and 4 m) – 5 phenomena;
- Thin coal beds (thickness less than 2.5 m) – 2 phenomena.

Depending on the inclination of the coal bed, the situation is as follows:

- High inclination (>45°) – 22 phenomena (17,6%);
- Average inclination (25°÷45°) – 66 phenomena (52,8%);
- Low inclination (5°÷25°) – 34 phenomena (27,2%);
- Horizontal (0°÷5°) – 3 phenomena (2,4%).

From the above it is shown that the average inclination coal beds are the most prone to the occurrence of the self-heating phenomena.

2.2.3. Situation of phenomena according to the type coal mining applied or mining work in which the phenomenon occurred.

From the analysis of the phenomena emerged during the studied period, it results that they occurred in long walls with individual support or in mechanized coalfaces, SCRI coalfaces, undermined coal beds, as well as in mine workings for preparation of coalfaces, the centralized situation being presented in Table 2.

***Table2**. Situation of phenomena depending on the type coal face or mining work*

No.	Mining unit	Recorded phenomena							
		Longwalls		SCRI coalface		Undermined coal bed		Other mine workings	
		Number	%	Number	%	Number	%	Number	%
1	Lonea	9	30	2	6,67	10	33,33	9	30
2	Petrila	-	-	1	9,1	6	54,54	4	36,36
3	Livezeni	6	35,29	-	-	4	23,53	7	41,18
4	Aninoasa	1	25	1	25	1	25	1	25
5	Vulcan	1	5,56	4	22,22	8	44,44	5	17,78
6	Paroșeni	1	50	-	-	-	-	1	50
7	Lupeni	1	2,86	-	-	23	65,71	11	31,43
8	Bărbăteni	-	-	-	-	4	80	1	20
9	Uricani	2	66,67	-	-	1	33	-	-
Total		21	16,8	8	6,4	57	45,6	39	31,2

According to the data from the table above, it is noticed that the highest share of the self-heating phenomena occurred in undermined coal beds - 45.6%, followed by the phenomena occurred in the area adjacent to these works by 31.2% , the phenomena occurring in longwalls have a weight of 16.8%, while those in SCRI coalfaces only 6.4%, mentioning that this method has not been used anymore since 2003.

By analysing the place of occurrence of phenomena studied, 86 (68.8%) of the 125 occurred in the goaf and 39 (31.2%) in the coal massif.

2.3. Statistical analysis of self-heating phenomena according to the period of the year

By eliminating stuffing fires and methane ignitions, the distribution of the occurrence of self-heating phenomena / endogenous fires according to the period (season) of the year is as follows:

Winter - 28 phenomena;
Spring - 26 phenomena;
Summer - 26 phenomena;
Autumn - 40 phenomena.

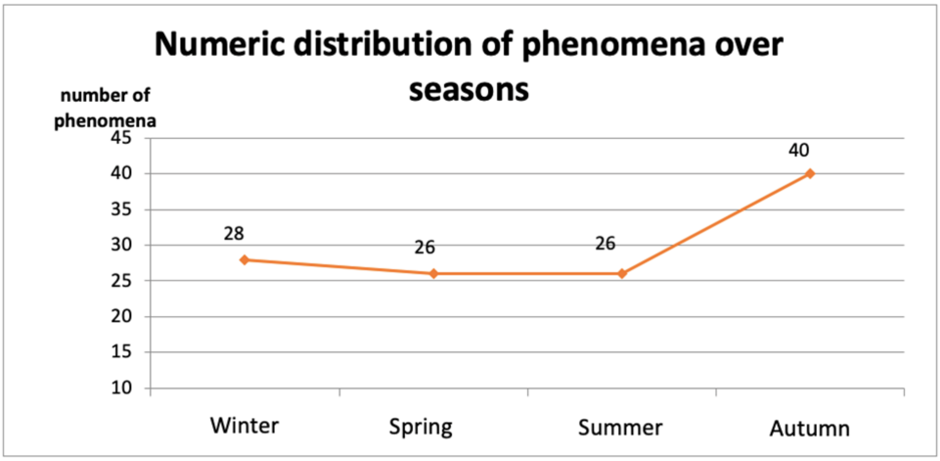

Fig. 6. Numeric distribution of phenomena over seasons

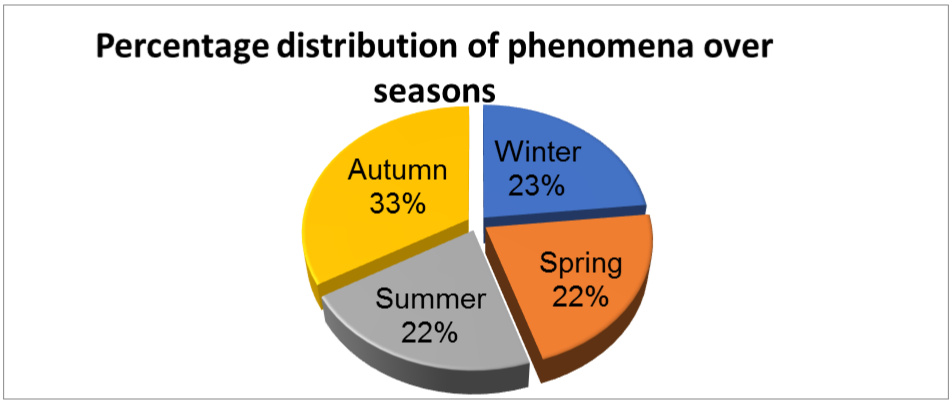

Fig. 7. Percentage distribution of phenomena over seasons

It is noted that autumn is the period of the year when the self-ignition are the most common, during this period the fluctuations of atmospheric pressure are the most sudden and with the highest amplitudes, as well as the temperature differences between night and day.

It is thus demonstrated that they have a direct, very important influence on the emergence and development of the self-heating phenomena. These influences are felt at the level of the mining works by increasing and decreasing the depressions on goaf or the fissures in the massif, thus generating fluctuations in the air flow circulated through the mining works.

2.4. Establishing the causes leading to self-heating phenomena

2.4.1. Identifying the causes which led to the occurrence of self-heating phenomena

As a result of the research of each phenomenon, the research teams highlighted the main causes of their occurrence, which are quite numerous and can be divided into the two main categories: objective (generated by geological factors) and subjective (generated by the manner of coal exploitation).

Table 3 presents a centralized situation on the causes that led to the occurrence of spontaneous combustion on each mining unit in part and in total.

***Table 3**. Causes which led to self-heating phenomena*

No.	Cause / Mining Unit	Lonea	Petrila	Livezeni	Aninoasa	Vulcan	Paroșeni	Lupeni	Bărbăteni	Uricani	Total
1	Aerodynamic links between active workings and the goaf or with fault systems	21	10	12	2	15	-	23	5	2	90
2	Improper insulation of inactive mine workings	1	2	6	2	4	1	12	1	1	30
3	Improper ventilation	6	-	1	-	1	-	2	-	1	11
4	Not applying measures to prevent self-heating phenomena	8	-	2	1	1	1	14	-	-	27
5	Cracks in the massif	3	2	2	-	2	1	10	1	-	21
6	Non-observance of the working technology with consequences in the evolution of self-heating phenomena	20	2	5	3	12	-	13	4	3	62
7	Complete non-use of coal, including unsuitable cleaning of	8	-	9	1	5	-	5	-	-	28

	the coal										
8	Undermining roof layers	-	-	-	-	1	-	-	-	-	1
9	Collapses occurred in coal faces or preparatory works	-	1	1	-	-	-	-	-	-	2
10	Fire reactivation / old self-heating phenomena	1	2	-	-	3	-	4	-	-	9
11	Methane ignitions	-	-	1	-	-	-	1	-	1	3

Following the analysis of the causes of self-heating phenomena, from the 125 cases analysed, the following can be noted:

- The most common cause is the "aerodynamic connection between the active works and goaf" in 90 cases;
- The following identified cause as frequency is " Failure to comply with the working technology" - 62 cases;
- A significant share in the occurrence of these phenomena have also the causes such as " Inappropriate insulation of inactive mining works" - 30 cases, " the non-exploitation of coal" - 28 cases, "not applying preventive measures" - 27 cases and "cracks in the massif" - 21 cases;
- The other causes add up to 26 other cases.

2.4.2. The link between the causes of self-heating phenomena and the exploitation method

Analysing the links between the causes that led to the occurrence of the self-heating phenomena and the type of the exploitation method, for the 125 phenomena analysed between 1997 and 2017, three types of exploitation methods were identified: classic coalfaces, SCRI coalfaces, undermined coal beds. Thus, for the three methods, the following causes were identified:

a) Classic coalfaces

- Failure to comply with the working technology;
- Air circulation through the goaf;
- Un-cleaned coal in the goaf;
- Superficial insulation of the upper part;
- Not-abducted support in the head gallery;
- Not applying self-heating preventive measures;
- Non-closure of the roof in the goaf and creation of air pockets.
- Inappropriate insulation of inactive mining works

b) SCRI coalfaces

- Failure to comply with the working technology;
- Leaky ventilation structures;
- Air circulation through the goaf;
- Un-cleaned coal in the goaf;

- Low advancing rate;
- Undersized pillars and the cracks in them;
- Improper ventilation.

c) Undermined coal beds

- Failure to comply with the working technology;
- Air circulation through the fissured area;
- Leaky ventilation structures;
- Air circulation through the goaf;
- Cracking of coal in the intersection area of the coalface with the directional galleries;
- Non-closed upper mine works or closed superficially;
- Not applying self-heating preventive measures;
- Un-cleaned coal in the goaf;
- Delayed commissioning of coalfaces or low rate of advancement;
- Stopping the coalface and delaying the unravelling and insulation of the goaf;
- Cracking of the coal massif due to the fault system in the area;
- Circulation of air towards heated areas or old fires.

2.4.3. The link between the causes of self-heating phenomena and the geological parameters of the layers

As shown before, the occurrence of self-heating phenomena is also influenced by the geological parameters of coal beds, such as thickness, inclination, and tectonics.

From the analysis of the causes that led to the occurrence of the 125 phenomena in the studied period, centralized in Table 4, in relation to the thickness and inclination of the beds, the following can be concluded:

- In case of thick coal beds, all causes of phenomena occurrence were identified (100%);
- For average-thickness coal faces, 36.4% of the causes of phenomena occurrence were identified;
- For thin (thin) coal beds, 27.3% of the phenomena occurrence causes were identified;
- In the case of high-inclination coal beds, 90.9% of the phenomena occurrence causes were identified;
- 81.8% of the causes were found in the case of average-inclination coal beds;
- In the case of low-inclination coal beds, 81.8% of causes were identified;
- For horizontal coal beds, 45.4% of causes were identified

***Table 4**. The link between the causes of self-heating phenomena and the geological parameters of the*

No.	Cause	Layer inclination				Layer thickness		
		0°÷5°	5°÷25°	25°÷45°	>45°	Thin	Average	Thick
1	Aerodynamic links between active workings and the goaf or with fault systems	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Improper insulation of inactive mine workings	Yes	Yes	Yes	Yes	Nu	Yes	Yes
3	Improper ventilation	No	Yes	Yes	Yes	No	No	Yes
4	Not applying measures to prevent self-heating phenomena	No	Yes	Yes	Yes	No	No	Yes
5	Cracks in the massif	No	Yes	Yes	Yes	No	No	Yes
6	Non-observance of the working technology with consequences in the evolution of self-heating phenomena	Yes	Yes	Yes	Yes	Yes	No	Yes
7	Complete non-use of coal, including unsuitable cleaning of the coal	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	Undermining roof layers	No	No	No	Yes	No	No	Yes
9	Collapses occurred in coal faces or preparatory works	No	Yes	Yes	Yes	No	No	Yes
10	Fire reactivation / old self-heating phenomena	No	No	Yes	Yes	No	No	Yes
11	Methane ignitions	Yes	Yes	No	No	No	Yes	Yes

3. CONCLUSION

After analyzing data of the 125 phenomena identified in 1977 ÷ 2017, it is observed that during the analysed period most phenomena occurred at Lupeni mining unit - 35, followed by Lonea mining unit with 30 phenomena, 118 of them occurred in coal bed no. 3, representing 94.4% of the total phenomena, the remaining 7 phenomena being distributed: 4 phenomena (3.2%) in the coal bed no. 5, respectively 3 phenomena (2.4%) in coal bed no. 13.

By analysing the place of occurrence of phenomena studied, 86 (68.8%) of the 125 occurred in the goaf and 39 (31.2%) in the coal massif, and according to the period (season) of the year, it is noted that autumn is the period of the year when the self-ignition are the most common.

Following the analysis of the causes of self-heating phenomena the most common cause is the "aerodynamic connection between the active works and goaf".

Analysing the links between the causes that led to the occurrence of the self-heating phenomena and the type of the exploitation method three types of exploitation methods were identified: classic coalfaces, SCRI coalfaces, undermined coal beds.

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STUDY ON THE SELF-HEATING PHENOMENON FROM THE UNDERMINED COAL BED NO.3, COAL FACE 3, BLOCK VI, ELEVATION 320, VULCAN MINE UNIT

MARIUS ROMAN ROGOBETE [1]

Abstract: *Worldwide there is a growing range of mathematical models that try to meet the requirements of studying the causes of spontaneous combustion, and how to prevent and combat them. Correlation of these models with realities in the field is the next major challenge, taking into account the many variables that appear in the description of these phenomena. Thus, by conducting a case study of a self-heating phenomenon, it is aimed to answer the question whether the current mathematical models can be used on a general scale or are still at the particular model level for certain strict conditions of coal beds.*

Keywords: *modelling, spontaneous combustion, goaf*

1. INTRODUCTION

The concept of "model," so much used in modern science, is relatively new, but the modelling method is as old as people's preoccupations for scientific knowledge. Scientists of all time have used "models" in the most diverse areas of scientific knowledge. Until recently, they used modelling without using the term.

We can assume that the model is an isomorphic representation of reality, which, providing an intuitive and yet rigorous image, in the sense of the logical structure, of the phenomenon studied, facilitates the discovery of links and laws impossible or very difficult to find on other paths [1].

2. PRESENTATION OF MATHEMATICAL MODELS ON THE OCCURRENCE AND DEVELOPMENT OF COAL SELF-HEATING PHENOMENA

In 2008, a group of Chinese researchers presented a study on the identification of areas of the goaf prone to self-heating, within the mechanized longwalls and undermined coal beds. [3]

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The conclusions of this study, with regard to the risk of spontaneous combustion inside the goaf, reveals that it is divided into three areas according to the air flow rate, namely: the high airflow area (the area where the heat exchange of coal and air is fast enough to prevent temperature rise), low air velocity area (low ignition risk due to lack of oxygen) and critical air velocity area.

It is also indicated that the high risk area of spontaneous combustion is quite extensive. The distance from the critical area of the goaf in the intersection with the fresh air supply junction is quite long, ranging from 35 to 160 m. This is due to the high permeability of the goaf due to its non-closure near the pillar and the continuous supply with fresh air in this area. The critical area in the intersection section with the return air exhaust gallery is relatively short compared to the intersection with the fresh air intake gallery, ranging from 28 to 100 m. The high risk spontaneous combustion area in the middle zone of the coal face is limited to a length of 15 to 75 m behind the face.

Another study on the development of a mathematical model for the temperature distribution in the goaf was conceived by another group of Chinese researchers led by Y. Wang [4].

The temperature trend is similar in both the air inlet area and the air outlet area of the goaf. Behind the face, the temperature rises rapidly to the maximum reached value and then decreases slightly. The maximum temperature in the goaf, in the fresh air inlet area is higher than that from the return air exhaust area. The maximum temperature in the fresh air inlet area is about 55 m from the face, on the area of air outlet the maximum temperature is recorded at about 30 m from the work face. Also, the simulation in this study reveals that the area with spontaneous combustion risk in the goaf differs at the entrance, respective at the exit.

The results of the simulation of the temperature increase process in the goaf are shown in Figure 1. They show that along the fresh air inlet area, the temperature rise rate is much higher than that in the return air exhaust area.

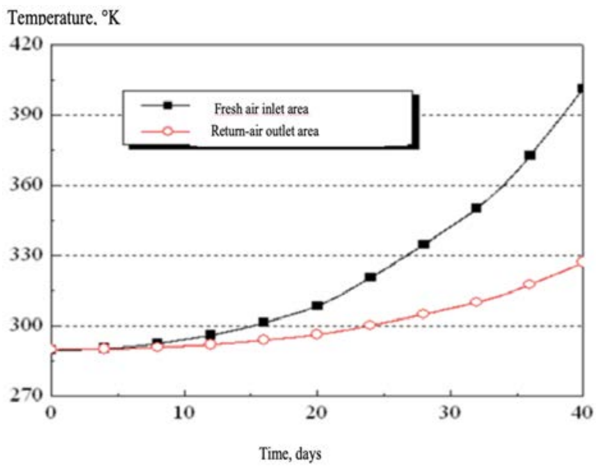

Fig. 1. *Evolution of the temperature rise process in the inlet and outlet areas of the goaf*

In order to study the relationship between the air flow rate and the spontaneous combustion, the air flow from 1400 m^3 / min (case 1) to 2000 m^3 / min (case 2) was simulated.

In Figure 2 and Figure 3 are presented the evolution of temperatures in the inlet and outlet areas of the goaf in the two cases.

It is noted that once with the increase of the air flow, the oxygen flow in the goaf increases, as a result the temperature in the goaf also increases, the risk of spontaneous combustion being much higher.

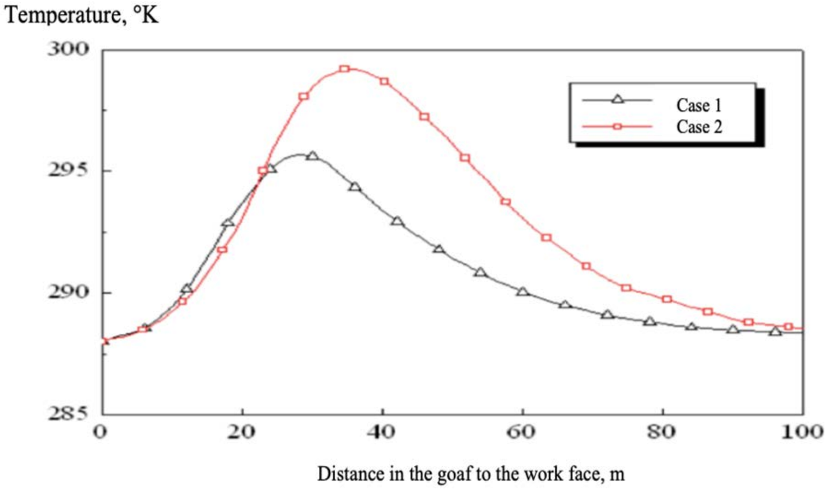

Fig. 2. *The distribution of temperatures in the return-air outlet area for the two cases*

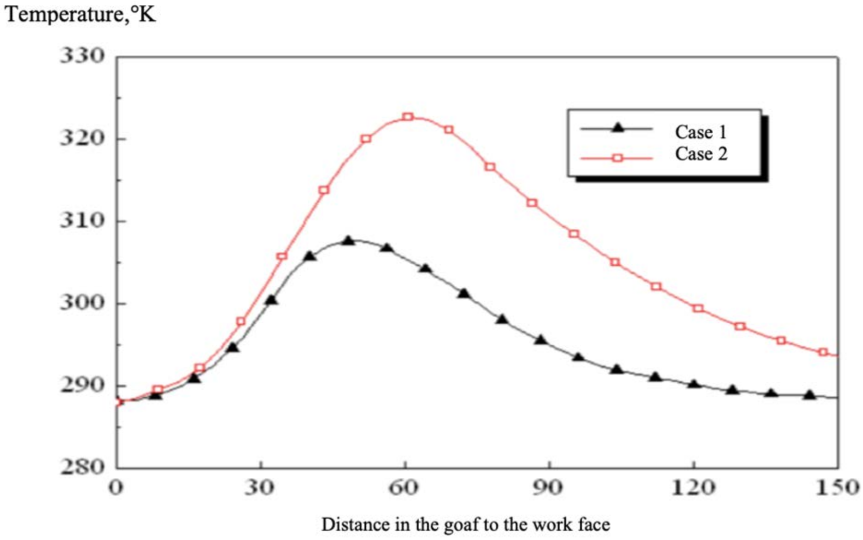

Fig. 3. *The distribution of temperatures in the fresh-air inlet area for the two cases*

By comparing the two curves, it can be noticed that at a higher air flow, the oxygen flow in the goaf is higher and the reaching of the critical ignition temperature of the coal is achieved in a shorter time, the risk of spontaneous combustion being much higher. Therefore the air flow rate must be controlled and it should not be very high.

In his study "Evaluation and Management of Spontaneous Combustion of Coal" [2] L.L. Sloss starts from the principle that the main cause of the occurrence of spontaneous combustion of coal is the exposure of coal from a limited space to the contact with oxygen. Increasing the air flow through the coal bed can reduce the risk of harmful gases accumulation, but it also brings oxygen in the exploited goaf, hence the need to maintain a balance of the gases from the goaf so that the risk of spontaneous combustion remains as low as possible.

3. STUDY ON THE SELF-HEATING PHENOMENON FROM THE UNDERMINED COAL BED NO.3, COAL FACE 3, BLOCK VI, ELEVATION 320, VULCAN MINE UNIT

The coal bed that is the subject of this study is an undermined coal bed, shown schematically in *Figure 4.*

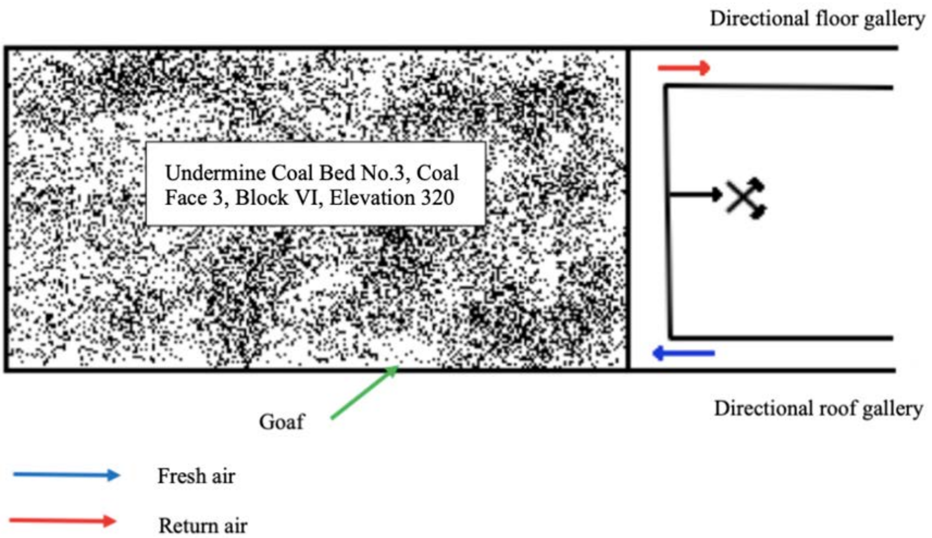

Fig. 4*. Base diagram of coal bed no.3, coal face 3, block VI, Vulcan mine unit*

In the goaf area, layer 3 has an inclination of 32 °, with an average thickness of 27 m, the exploitation is carried out in descending order, in horizontal slices, according to the undermined coal bed operating method for thick layers and medium inclination

($\alpha_{STRAT} = 25^0 \div 45^0$) [5] . The height of the base slice is 2.5 m and the thickness of the undermined bed is7.5 m (*Figure 5*).

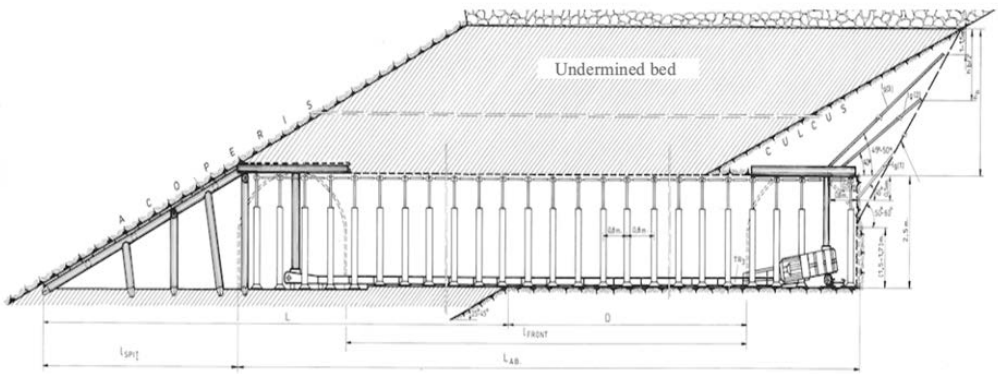

Fig. 5*. Section along the undermined coal bed , in horizontal slices*

Coal from layer 3, block VI from Vulcan mine unit, is a coal with self-ignition tendency, having a calorific power of 3300 ÷ 3500 Kcal / Kg [6].

Until the distillation gases appeared in the coal bed, it advanced 48 m from the starting line, the average length of the coal bed on the monitored area was 52 m. The air flow for ventilation of the coal bed was 250 m^3 / min (4.17 m^3 / s) [7].

The measurements were performed with Drager 5000 multigas devices, in the goaf at approx. 1m behind the support. The highest values of carbon monoxide concentration in each day of the monitoring period of this coal bed were taken into account. The monitoring was carried out for a period of 30 consecutive days (from the occurrence of distillation gas to the ultimate combat of the phenomenon).

Throughout the presence of carbon monoxide in the monitoring area, methods have been applied to fight against the phenomenon and to prevent its amplification (sewage of the goaf with power plant ash, spraying of aerosol-inhibiting solutions from the class of phosphates, introduction into the goaf of water with foam solutions etc). [8]

For the extraction of coal from the undermined coal bed, the working technology specific to the undermining operation behind the face line, in the case of coal evacuation on 3 beams, is respected *(Figure 6)* [5]:

Cutting coal at the front of the base slice by punching-blasting (phases I and II);

Console beam lifting, ceiling banding, evacuating coal discharged from the bottom of the base slice, support beams in the console and mesh banding of the face (phases II-III);

Gradual evacuation / discharging of coal from the undermined coal bed(Phase III);

Assembling the conveyor from coal face to the new alignment (the middle aisle of the beams), shortening the conveyor from the transport gallery and supporting the intersections (phase IV);

Managing the mining pressure (Phase V) by catching the pillars and the last row of beams.

During these stages the free air circulation through the coal face varies from 6.25 m^2 to 9.375 m^2.

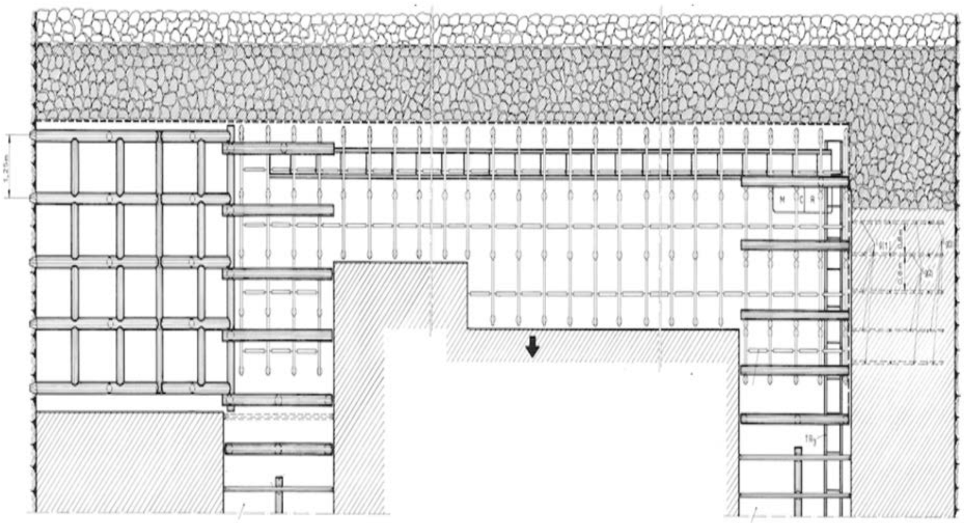

Fig. 6. *Base plan of the undermined coal bed*

In order to establish a relationship between the carbon monoxide concentration, the distance from the intersection with the air inlet in the coal face and the evolution of the depression created on the goaf, it was considered that the depression created by the general ventilation installation was constant, the differences emerging from the evolution of the atmospheric pressure and from modifying the free section of the coal face according to the working steps in the coal face. Thus the *value* Δh taken into account is:

$$\Delta h = (h_0 - h) \times c \text{ , (mmHg)}$$

where:

h_0 average multi-annual atmospheric pressure (707 mmHg);

h –atmospheric pressure measured during the collection of gas samples from the coal face;

c –coefficient which takes into account the free section of the coal face according to the working phases

Data collected from the field during the monitored period was centralized in *Table 1.*

***Table 1.** Statistic data on the self-heating phenomenon from the undermined coal bed no.3, coal face 3, block VI, Vulcan mine unit*

Day	**Working phase**	**Atmospheric pressure (mmHg)**	**Difference of pressure after correction (mmHg)**	**Concentration of carbon monoxide (ppm)**	**The distance from the intersection with the directional roof gallery (m)**
1	beams lifting	705	-1,68	16	14,4
2	beams lifting	699	-6	28	31,2
3	coal evacuation	701	-3,96	18	20,8
4	coal evacuation	704	-1,98	16	19,2
5	mining pressure control	704	-3	22	24,8
6	beams lifting	701	-5,52	20	22,4
7	beams lifting	695	-10,08	29	20,8
8	beams lifting	701	-4,5	19	17,6
9	coal evacuation	699	-5,28	10	11,2
10	coal evacuation	706	-0,66	12	11,2
11	mining pressure control	711	4	14	12,8
12	beams lifting	700	-6,51	17	15,2
13	beams lifting	699	-6,8	13	14,4
14	beams lifting	705	-1,52	8	7,2
15	beams lifting	705	-1,4	6	6,4
16	coal evacuation	704	-1,98	10	8
17	coal evacuation	705	-1,32	6	6,4
18	mining pressure control	705	-2	18	16
19	beams lifting	707	0	14	12,8
20	beams lifting	706	-0,9	14	12
21	beams lifting	695	-10,2	17	14,4
22	beams lifting	703	-3	16	17,6
23	beams lifting	712	3,5	10	12,8
24	coal evacuation	712	3,3	8	6,4
25	coal evacuation	708	0,66	8	6,4

26	coal evacuation	706	-0,66	6	6,4
27	mining pressure control	712	5	12	8
28	beams lifting	715	7,44	9	5,6
29	beams lifting	712	4,25	6	4,8
30	beams lifting	708	0,76	2	4,8

By analysing the data in *Table 1* and graphically presented in *Figure 7*, it can be observed that there is a dependence of the concentration of carbon monoxide on the evolution of the depression created upon the goaf. It is also noted that the distance where the maximum carbon monoxide concentrations occurred compared to the fresh air intake gallery is dependent on the created depression. Thus, with the decrease of the pressure difference, resulting in the creation of an additional depression on the goaf, the value of the concentration of the distillation gases, represented in this case by the carbon monoxide, tends to increase and the area where the maximum concentration is recorded the area in which the distillation gas enters the ventilation circuit moves towards the maximum depression area, namely to the junction of the coal face with the directional return-air exhaust gallery (directional floor gallery).

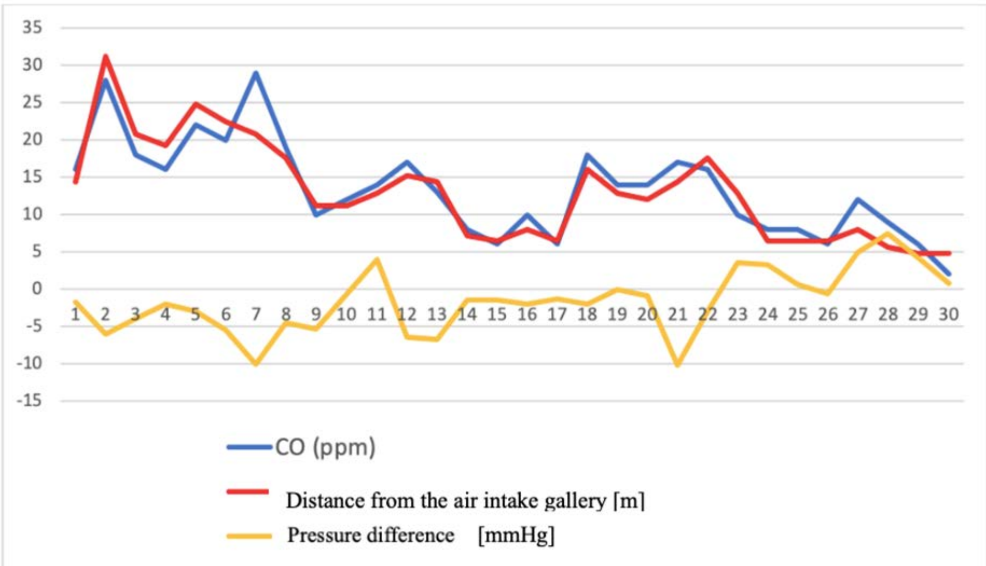

Fig. 7*. Time evolution of carbon monoxide concentration*

Another conclusion of this study is that the fireplace of this self-heating phenomenon is located in the goaf near the intersection with the directional roof gallery, which is also the fresh air inlet gallery. Depending on the depression created on the goaf, the migration of the distillation gases to the outlet is made from 5 m to 31 m from the intersection with the roof directional gallery.

In addition to the measures applied to fight against the phenomenon, it was observed that the removal of the front line of the fireplace had a decisive role in reducing the effects of this phenomenon, during the monitored period, the coal face had an advance of 6.25 m, and by closing the voids in the goaf, the fresh, oxygen-rich air has not reached the heated area, thus leading to a regression of the self-heating.

4. CONCLUSIONS

Currently, there are many studies on coal self-heating phenomena (spontaneous combustion), the global trend of researchers being to create mathematical models to explain the phenomenon which to foresee the possibility of its occurrence.

By analysing the data from the self-heating phenomenon from the undermined coal bed no.3, coal face 3, block VI, elevation 320, Vulcan mine unit, it can be observed that there is a dependence of the concentration of carbon monoxide on the evolution of the depression created upon the goaf. It is also noted that the distance where the maximum carbon monoxide concentrations occurred compared to the fresh air intake gallery is dependent on the created depression. Thus, with the decrease of the pressure difference, resulting in the creation of an additional depression on the goaf, the value of the concentration of the distillation gases, represented in this case by the carbon monoxide, tends to increase and the area where the maximum concentration is recorded the area in which the distillation gas enters the ventilation circuit moves towards the maximum depression area, namely to the junction of the coal face with the directional return-air exhaust gallery.

The performed case study, confirms the conclusions drawn from computer modelling, regarding the areas which are the most vulnerable to self-ignition, these being proven to be in the goaf, in the intersection with the fresh air intake gallery, this area being located between the area where the amount of oxygen in the goaf is low and the area where the air circulation rate is large enough to dissipate the heat produced by the oxidation of the coal remaining in the goaf.

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DETERMINATION OF FLAMMABILITY PARAMETERS AND BURNING GASES, IN ORDER TO REDUCE RISKS IN THE FIRE OR EXPLOSION TYPE EVENTS

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Abstract: The study of the characteristics of fires or explosions, as well as factors influencing their production and development, leads to the increase of the fire / explosion expertise capacity, the expansion of the knowledge field related to these phenomena, also increasing the health and safety at work. Because of the random evolution, there cannot be two fires the same. A number of factors are involved in the development of a fire: the nature and positioning of combustible materials, the shape and dimensions of the room, the thermal load, the openings to the outside, the location and mode of initiation of fires, etc. Following the similarity of these numerous factors, fire experiments on a natural scale produce very varied results. For the study and experimental determination of the flammability parameters of the different materials and the assessment of the fire behaviour, the following were made: the stand for vertical and horizontal burning determination according to SR EN 60695-11-10, the stand for determination of the ingress efficiency SR 652: 2009. Experimental determinations were performed with these stands. Also, the evolution of the concentration of the most significant gaseous effluents over time has been studied: carbon dioxide, hydrogen cyanide, nitrogen oxides, etc. Different polymeric materials such as polymethylmethacrylate, rubber, melamine was taken in consideration to study the nature and concentration of gaseous effluents. As a result of the combustion of the polymeric materials, high concentrations of gases with high toxicity, namely: carbon dioxide, hydrogen cyanide, nitrogen oxides, and the distribution of these concentrations were determined during the tests. The nature of the resulting gas is dependent on the composition of the burning material, such as for example burning melamine, resulting in significant amounts of hydrogen cyanide.

Keywords: *fire, toxic gaseous, flammability*

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1. INTRODUCTION

Combustion processes are oxidation reactions of some substances, resulting in different amounts of heat. For the complete oxidation of combustible elements, a minimum amount of oxygen is contained in a minimum amount of air. Combustion carried out in the presence of the minimum required air is called stoichiometric burning or theoretical combustion. Incomplete combustion processes result in significant amounts of carbon dioxide. Calamar et al. 2017.

The main gases of toxic, asphyxiating, irritant, flammable nature, etc., that can be generated from fires / explosions are:

CO_2-carbon dioxide and CO-carbon monoxide are common combustion product and significant amounts of

HCl - hydrochloric acid, is generated by the combustion of polyvinylchloride and chlorine-protected synthetic materials (chlorinated polyesters);

HCN - hydrogen cyanide is released from polyamides, polyacrylonitrile, polyurethane, polybutadiene, polystyrene and nitrate polymers, for example, polyurethane releases the highest amount of HCN at temperatures of about 1000 ° C, HF - hydrofluoric acid is released in the case of polytetrafluoroethylene. Strec A.A. et al., 2008.

NOx (N_2O, NO, NO_2) is released by burning polyacrylonitrile, polyamide and cellulose, styrene

NH_3 - ammonia, is an irritant gas; in the case polyamide combustion has a maximum permissible concentration of 50 ppm, incomplete combustion products such as tar, aliphatic or aromatic hydrocarbons in the form of very fine particles / aerosols, which can cause bronchial / pulmonary damage. Gann et. al. (2010)

Smoke combustion products are fatal to a large extent because in their presence people become disoriented, suffer respiratory disturbances, lose their knowledge and physical mobility. After a period of hyperventilation of the body, as a result of inhalation of irritant gases, the main causes leading to death are the inhalation of carbon monoxide (CO) and hot gases. Abdulrhmann, 2015.

The most significant toxic effluents from common fires are: carbon monoxide (CO), hydrogen cyanide (HCN), carbon dioxide (CO_2), hydrochloric acid (HCl) and nitrogen dioxide (NO_2). Carbon monoxide is considered the most dangerous toxic gas because it can be found in large quantities at all fires. The importance of each toxic gas for a specific fire must reflect both its toxicity and the concentration in which it forms. Exposure time is also important for determining the effects of toxic gases. Carloganu, 1986.

Risks / hazards may increase / may become greater when the listed substances react with each other or react with other substances.

2. DETERMINATION OF FLAME PROPAGATION TESTING METHODS AND RESULTS

Determination of the flame propagation in the vertical plane for cables can be made by optical cables according to the European standard IEC 60332-1 (3), thus the method of testing the burning rate of the plastic materials from which the cable sheath is made. Fire hazard tests (SR EN 60695-11-10) Part 11-10: Test flares.

Horizontal and vertical flame test methods Horizontal and vertical flame test methods of 50W flame are based on the fixation of the test specimen horizontally and vertically, determining the vertical and horizontal firing rates. The test or preconditioning test leads for 8 hours at 70 ° C. Test specimens have a size of 125mm ± 5mm. Diameters used for testing: 8mm and 4mm. Or conditioning two sets of test materials at 23 ° C, they were marked at a distance of 25mm from the longitudinal axis. The flame burner is applied for 10 seconds or removed if the flame front exceeds the 25mm mark.

Smoke combustion products are fatal to a large extent because in their presence people become disoriented, suffer respiratory disturbances, lose their knowledge and physical mobility. After a period of hyperventilation of the body, as a result of inhalation of irritant gases, the main causes leading to death are the inhalation of carbon monoxide (CO) and hot gases. Szollosi-Mota et.al. (2018)

The test method was developed in accordance with SR EN 60695-11-10 Part 11-10: Test flames.

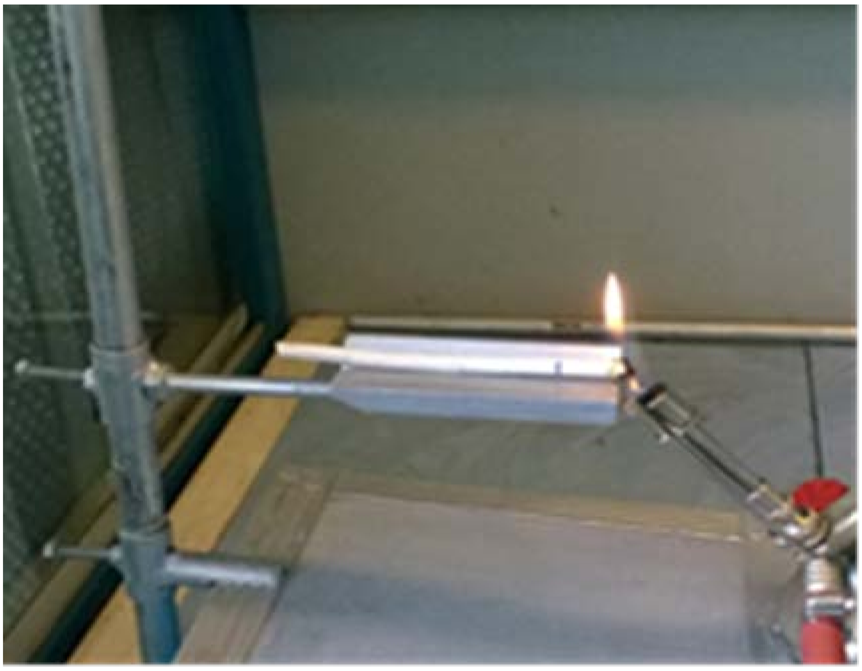

Fig. 1. Testing of flame propagation velocity

Table 1. Determination of horizontal flame propagation velocity for cable 4mm diameter

Type of cable	**Time at which the flames were applied [s]**	**Flame propagation rate [mm]**	**Flame propagation velocity [mm/min]**	**Average propagation velocity [mm/min]**
Cable diameter 4mm	30	8	16	9,6
		10	20	
		10	20	
		9	18	
		7	14	
		11	22	
		12	24	
		10	20	
		9	9	
		10	10	

Table 2. Determination of horizontal flame propagation velocity for cable 8mm diameter

Type of cable	**Time at which the flames were applied [s]**	**Flame propagation rate [mm]**	**Propagation velocity [mm/min]**	**Average propagation velocity [mm/min]**
Cable diameter 8mm	30	7	14	12,6
		8	16	
		6	12	
		5	10	
		6	12	
		5	10	
		6	12	
		7	14	
		8	8	
		5	10	

Testing was performed on test specimens on two types of cables with test diameters of 4 and 8 mm. The test tubes have a size of 125 mm ± 5 mm. Diameters used for testing: 8mm and 4mm. A timer was used to measure the flame time. Two sets of test materials were conditioned at 23°C, they were marked at a distance of 25mm from the longitudinal axis. The flame burner is applied for 10 seconds or removed if the flame front exceeds the 25mm mark.

Table 3. Determination of vertical flame propagation velocity for cable 8mm diameter

Type of cable	Time at which the flames were applied [s]	Length of burned cable [mm]	Propagation velocity [mm/min]	Average of propagation velocity [mm/min]
Cable diameter 8mm	10	20	120	109,6
		18	108	
		16	96	
		18	108	
		18	108	
		17	102	
		18	108	
		19	114	
		20	120	
		19	114	

3. METHOD OF DETERMINING FLAME-RESISTANCE AND RESULTS

Determination of flame-retardant efficiency: SR 652: 2009 Wood, plywood, chipboard, wood fibre boards. Considering the parameters described in the standard, a test stand was carried out by a method of laboratory determination of the effectiveness of flame retardant products applied on wood, plywood, chipboard. The test consists in determining the mass loss of flameproof specimens subjected to combustion. After the burner gas supply is interrupted, determine the duration of residual flame or residual incandescence. The test method is based on determining the mass loss of flame retardant specimens subjected to combustion.

Table 4. Determination of flame retardant efficiency

Type of tested material	Loss of the specimen [%]	Thickness of specimens [mm]	Application time of flame [min]
Woods chips plates	24,88	10	15
Pal plates	13,24	15	15
Pal laminated plates	14,71	16	15
Plywood non-fire resisting	66,19	0,5	15
Slim plywood	73,99	0,3	15

Fig. 2. Testing of flame resistance

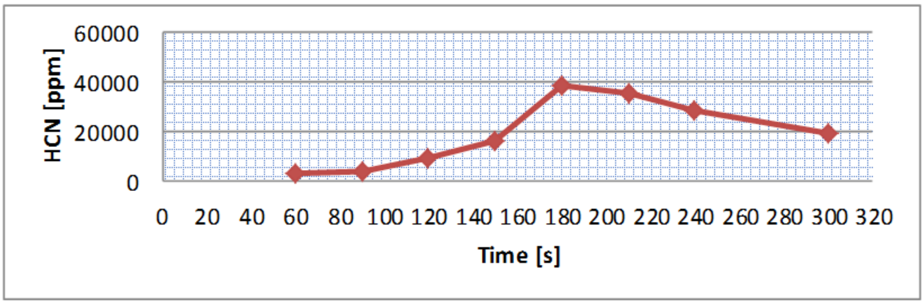

Fig. 3. Variation of concentration of hydrogen cyanide in time in the burning of melamine

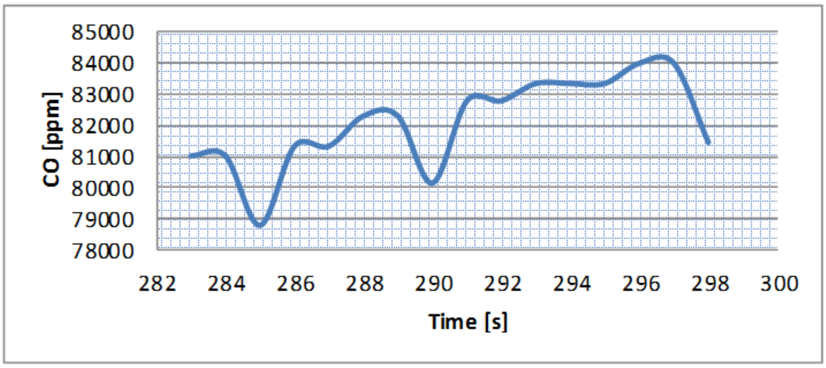

Fig. 4. Variation of concentration of concentration of carbon monoxide

The concentration of carbon monoxide and hydrogen cyanide increasing during the firing tests, and these gases are particularly very dangerous for human health.

4. CONCLUSIONS

The stand for determining the vertical burning rate was made and determinations were made using electrical cables of 4 and 8 mm diameter for which the vertical burning rate of the test specimens was determined. Smaller cable samples (0.4 mm in diameter) showed a higher average firing rate compared to a larger diameter (0.8 mm diameter). The stand was made for determining the horizontal burning rate and determinations were made for two types of 4mm and 8mm cables. After making the determinations, it can be concluded that the average burning speed for the specimens is inferior to the larger diameter cable.

Toxic products formed in the fire are depending on the chemical reactions and combinations of the resulting products, leading to antagonistic, synergistic effects and other additional interactions. Their nature is directly related to the products involved in the fire and the thermal degradation conditions of the materials and substances. The most significant toxic effluents from common fires are: carbon monoxide (CO), hydrogen cyanide (HCN), carbon dioxide (CO), hydrochloric acid (HCl) and nitrogen dioxide (NO2). CO is considered the most dangerous toxic gas because it forms in large quantities at all fires. The test is designed to reproduce real fire conditions and it is essential to make appropriate observations to ensure that conditions are met.

Experimental determinations were made on smoke, nature and concentration of combustion gases by means of instrumental methods existing in the laboratory, respectively determination methods by electrochemical sensors, spectrophotometry, IR sensors, etc. The behaviour of different combustion materials was studied as follows: polymethyl methacrylate, melamine and rubber.

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SR 652: 2009 Determination of flame-retardant efficiency

SR EN 60695-11-10 Part 11-10: Test flames. Horizontal and vertical flame test methods Horizontal and Vertical Flame Test Methods 50W are based on fixing the test specimen horizontally and vertically, determining the vertical and horizontal firing rates

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IDENTIFICATION OF BURNING ACCELERATORS IN INVESTIGATION OF FIRES USING THE INFRARED SPECTROSCOPY METHOD (FTIR)

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Abstract: The combustion potentiality of a substance or explosive mixture can be identified by ascertaining the structure of their chemical compounds using several methods, including infrared spectroscopy (FTIR). The objective of this paper is to identify certain hazardous substances that have generated explosion or fire type events, by using modern techniques that consist in physical-chemical characterization of substances or their compounds. Infrared absorption spectra were assessed by using the attenuated total reflection analysis technique (ATR) and their evaluation was performed by using libraries within the device's software. The use of this technique is safe, being a convenient method in terms of sample preparation and quantity of sample used, the main advantage being the certainty of results.

Keywords: *ATR analysis, combustion, explosive mixture, hazardous substance, infrared spectroscopy*

1. INTRODUCTION

Fourier Transform Infrared Spectrometry has become one of the main techniques used when analyzing samples of particular specificity that require a non-destructive analysis. (Radu et al., 2012).

In this study some experimental results are presented, which, through the arguments brought, justify the importance of using this technique in elucidating aspects of the structural characteristics of certain types of evidence.

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The research was carried out on samples taken from material evidences, used and experimented in the elaboration of reports for technical expertise of explosion or fire type events.

The results of the spectrograms allow the identification of certain types of substances, specific to the event location. In the case of identification of the IR spectrum waveform numbers, specific for burning accelerators (e.g.: gasoline, diesel, oil, etc.), the team of researchers involved in the elaboration of the technical expertise report for the investigated event could correlate the FTIR data obtained with all other relevant elements, in order to determine the causes that led to the occurrence of the event (Ghicioi et al., 2018).

2. DETERMINATION METHOD

Fourier Transform Infrared Spectrometry (FT-IR) is a non-destructive technique that involves low analytical costs and fast responses. These features make FT-IR spectrometry one of the most widely used analysis techniques in physico-chemical analysis laboratories. The advantages of this technique have brought to specialists' attention and the problem addressed is very broad: the characterization of some substances in order to identify certain combustion accelerators. (Merticaru and Petroviciu, 2005).

Spectrometry is used both as a qualitative method for identifying the presence of a substance in a solution, as well as a quantitative method for identifying the concentration of a substance in a solution. The method can also be used to determine the equilibrium constant of a solution (Berthomieu and Hienerwadel, 2009).

The IR range of the electromagnetic wave spectrum contains radiation with wavelengths ranging from $0.8\ \mu m \leq \lambda \leq 1000\ \mu m$. This range can be divided into three sub-domains: near-infrared ($0.8\ \mu m \leq \lambda \leq 2.5\ \mu m$), mid and long wavelength infrared (between $2.5\ \mu m \leq \lambda \leq 25\ \mu m$) and far infrared (over $\lambda = 25\ \mu m$).

In most laboratories, Fourier Transform Infrared Molecular Absorption Spectrometry and Fourier Transform Raman Spectrometry are used as complementary techniques, since each of them exhibits certain aspects for a given sample (Varma et al., 1989; Birzescu et al., 2009).

3. APPARATUS

For the identification of combustion accelerators, the samples taken at the event site were analyzed by infrared spectrometry method with a FT-IR type equipment, Nicolet IS 50, made by ThermoScientific, with integrated ATR module with diamond crystal, with the range of 4000 - 400 cm^{-1} (Figure 1).

Fig. 1. (a) Nicolet IS50 Infrared Spectrometer equipment; (b) ATR module with diamond crystal and device for analyze of volatile substances.

Infrared absorption spectra were recorded at a resolution of 4 cm^{-1}, using ATR (attenuation of total reflection) analysis technique, as follows:

• Attenuation of total reflection, performed directly on the combustion residue samples - non-destructive analysis;

• Attenuation of total reflection, performed on n-hexane extract, with background read on solvent.

In order to identify the contaminants or compounds found in very low concentrations, the sample was subjected to an extraction operation using solvent (n-hexane), at room temperature.

The experimental data obtained was evaluated using the OMNIC software (Thermo Nicolet Corporation), as well as the dedicated libraries containing more than 40000 IR spectrograms (ThermoScientific, 2013).

4. RESULTS AND DISCUSSIONS

For the identification of certain combustion accelerators in fire events, two cases were analyzed:

a) A case where no combustion accelerators have been identified;

b) A case where combustion accelerators have been identified.

For each sample, a spectral analysis was performed directly on the residue, as well as an analysis of the n-hexane extract from the residue.

a) For the first case, 2 samples were taken from the site where the fire event took place and being analyzed in the Laboratory for Physico-Chemical Analysis, the samples representing the residues of textile materials and carbonized residues (Fig. 2).

Fig. 2. Scraps of textile materials – 1st case.

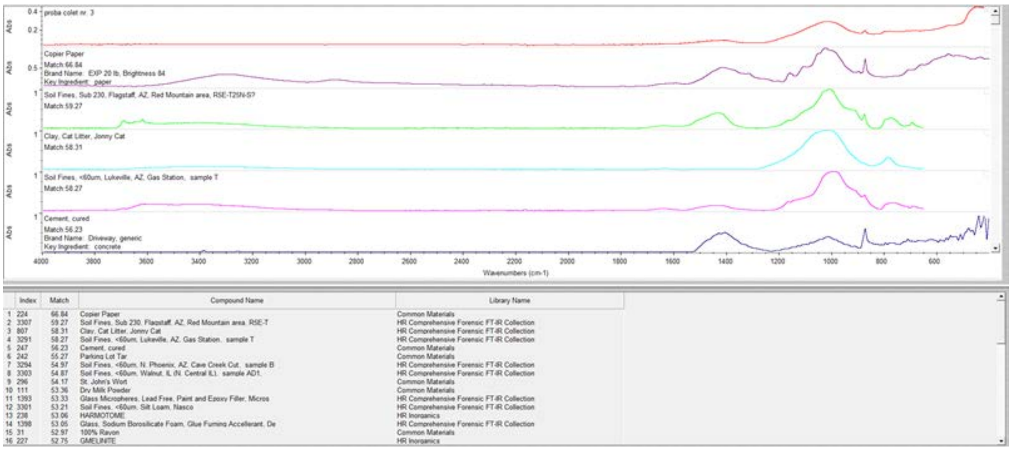

Fig. 3. IR spectrum of the textile material sample, untreated with n-hexane

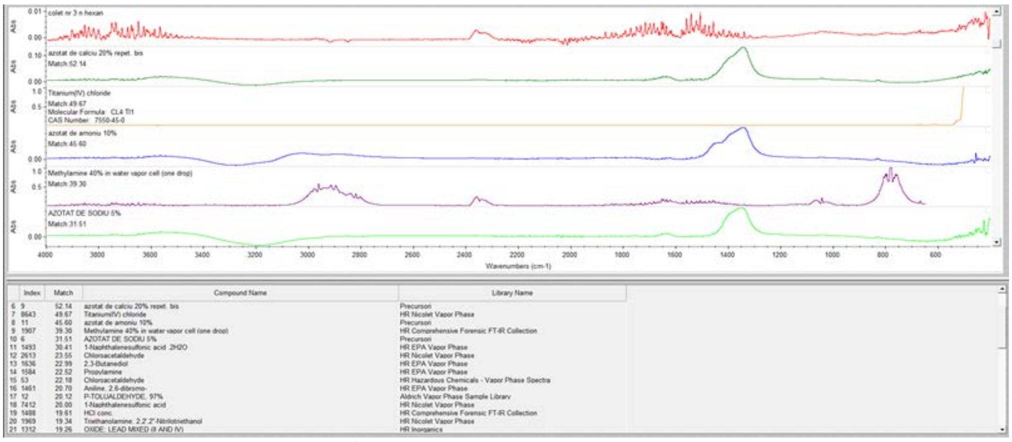

Fig. 4. IR spectrum of the textile material sample, treated with n-hexane

Figure 5 presents a sample consisting in carbonized residues, other than textiles.

Fig. 5. Sample consisting in carbonized residues, other than textile materials.

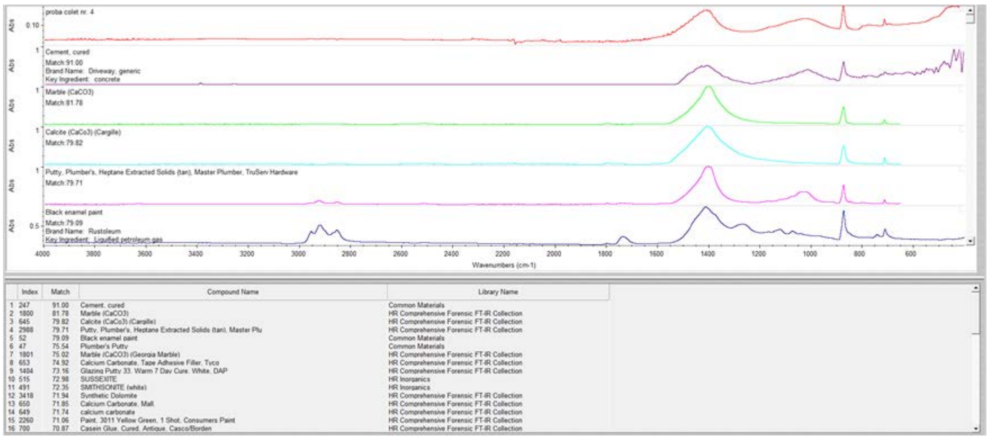

Fig. 6. IR spectrum of carbonized residues, other than textile materials, untreated with n-hexane

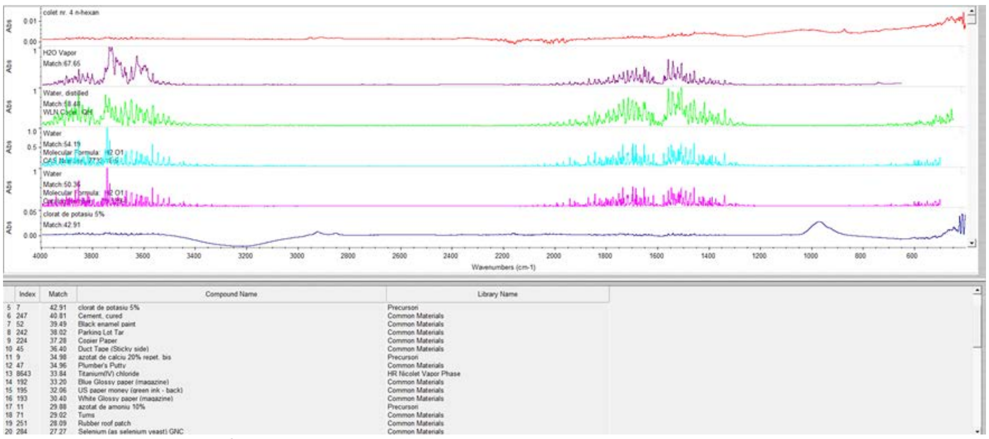

Fig. 7. IR spectrum of carbonized residues, other than textile materials, treated with n-hexane

In the two analyzed samples, no elements were identified that would lead to the existence of specific firing accelerators specific to the Arson type effects.

b) For the second case, 3 samples that were taken from the event site were analyzed in the Physical-Chemical Analysis Laboratory. The samples contained combustion residues (Fig. 8).

a) b) c)

Fig. 8. The three samples consisting in combustion residues.

For exemplification purpose, Figures 9 and 10 show the IR spectra of sample c), both before and after the treatment with n-hexane.

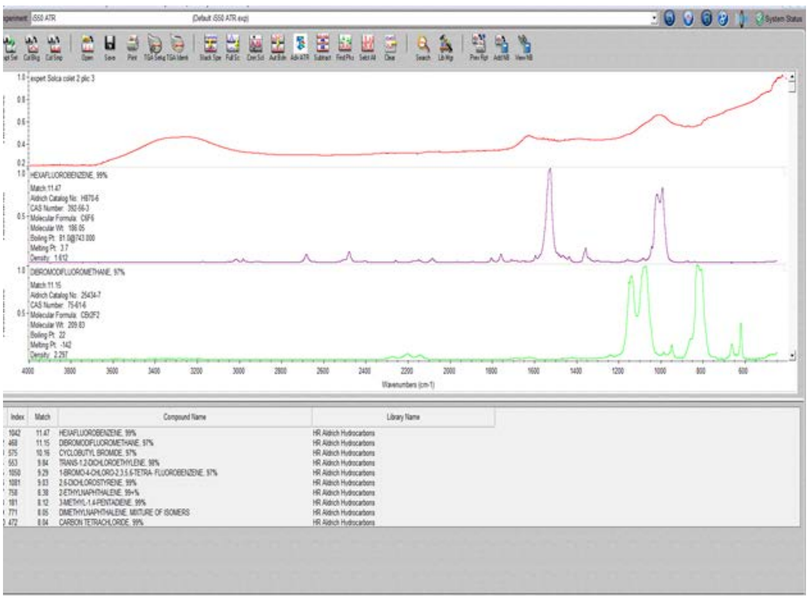

Fig. 9. IR spectrum for sample c), untreated with n-hexane.

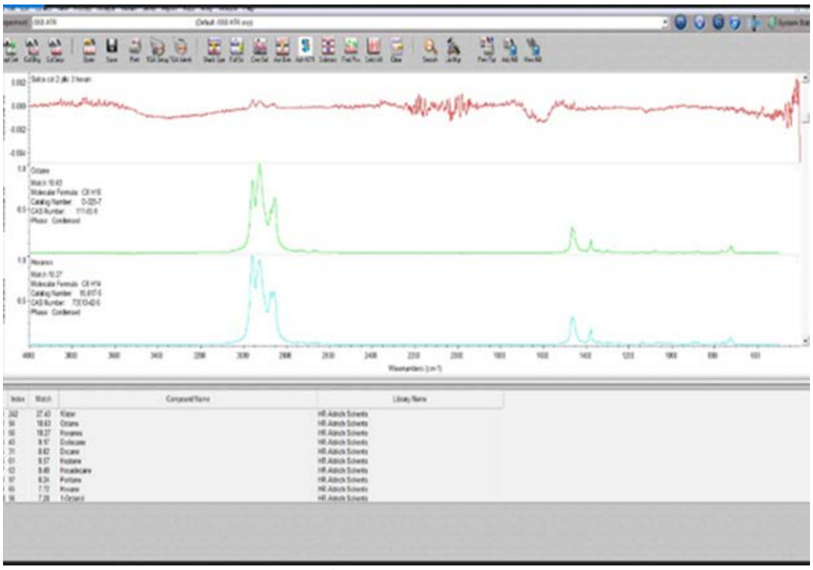

Fig. 10. IR spectrum for sample c), treated with n-hexane.

In this case, following the analysis carried out on the three samples, the ATR-FTIR analysis of n-hexane extract, there have been identified aliphatic hydrocarbons from the series of higher alkanols and aromatic hydrocarbons such as: pentane, hexane, heptane, octane, dodecane, cyclohexane, benzene, xylene, all these substances also being found in the chemical composition of petroleum products.

5. CONCLUSIONS

The ATR-FTIR spectral analysis method has proven to be an effective method for identifying the waveforms numbers specific to certain combustion accelerators and is particularly useful in investigating fire / explosion type events. The paper presents, in the second case under consideration, specific elements of petroleum products, which, together with other relevant data of the event, allow the confirmation of the Arson effect.

6. ACKNOWLEDGEMENTS

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STUDY ON INCREASING THE THERMAL PROTECTION OF HIGH-TEMPERATURE HELMETS USED BY FIREFIGHTERS

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NICOLETA-MONICA LOHAN [3]
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Abstract: Protective helmets are very important components of individual fire-fighting equipment. They have different roles including: protecting the head from throwing objects, protecting from high temperatures or electrical shocks. In order to be used, they must ensure the absorption of shocks in the upper part of the head, to have penetration resistance, to have lateral crush resistance, to provide protection against hot liquids and high temperature resistance. The helmet material has to provide the same properties when is exposed to 90 ± 5°C for 20 minutes in the area of the upper head and ear, and at 180 ± 5°C for 5 minutes in the area of the neck protector. At the moment, fire-fighting helmets are made of high-quality polymers. This paper aims to analyse the thermal behaviour of a new material useful for fire-fighting helmets: hot modelling material, under the form of a glass fibre-reinforced bismaleimide composite material, compared to a molded polypropylene injection. Thermal analysis will be performed using differential scanning calorimetry (DSC) and Dynamo Mechanical Analysis (DMA) and the thermal properties of the new material will be highlighted.

Keywords: *Personal Protecting Equipment, firefighter helmets, bismaleimide, high temperature resistance*

1. INTRODUCTION

Personal Protective Equipment (PPE) is the equipment intended to be worn or held by the worker to protect him against the risks that might endanger his health and safety at work, as well as any additional or accessory designed for that purpose, according to GD 1048/2006. PPE is part of the daily routine of all those working in the industry, construction and emergency services staff. Currently, Romania has one of the highest levels of incidents in Europe, with over 4,900 accidents at workplace being

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reported in 2016, of which 225 were fatal accidents, according to the Labor Inspection report (www.inspectiamuncii.ro).

One of the causes is the inappropriate choice and use of PPE (Bejinariu et al., 2017a). PPE includes the following components required for: head protection, leg protection, face protection, respiratory protection and body protection (Park et al., 2015). It should be noted that the use of protective equipment is the last priority in the process of preventing accidents at work; in principle, reducing or controlling risks at source should prevail (Mihai-Adrian et al, 2017, Babut and Moraru, 2018). Risk assessment is a first step in determining the type of protection required (Ivașcu et al., 2014, Moraru et al., 2013), followed by the training for an appropriate use of the equipment (Darabont et al., 2017a, Babut et al. 2011), as well as the correct implementation of the standards in force (Darabont et al., 2017b, Bejinariu et al., 2017b).

Combating fire is often described as a very dangerous activity (Ghani et al., 2017). According to statistical data, the dangers that endanger the safety of firemen's life can be divided into several categories, namely: building demolition, flashover explosion, fall from height, electric shock, gas poisoning, road accidents and other accidents (Kang et al., 2016). The probability of meeting high heat environments contributes to the dangers inherent in this occupation. Situations such as "flashovers" and high intensity fire are examples of circumstances in which anti-fire personnel can expect to face a high level of radiant heat flow. To ensure adequate protection against bodily injury and fire blazes, PPE is designed to isolate the wearer from the dangers of the environment and ensure the efficient performance of the work duties (Vigneswaran, and Arulmurugan 2014).

Appropriate head protection equipment is particularly important for the safety and protection of firefighters when they engage in small or large fires (Bălan et al, 2011). The helmet is designed to protect the head from flying objects, explosions, high temperatures, electrical shocks, and chemicals. Those helmets must meet certain specific thermal, shock, penetration or abrasion resistance requirements, in accordance with current standards.

In Romania, firefighting helmets in buildings and other structures must be tested and meet the mandatory performance requirements in accordance with SR EN 443:2008: shock absorption in the upper area of the head, penetration resistance, side impact resistance, radiant heat resistance, protection against hot liquids, as well as heat resistance. In general, a helmet consists of a cap and harness and other accessories. The cap is the visible part of the helmet made of materials resistant to temperature, vibration, impact and humidity. The most commonly used cap materials are high density polyethylene (HDPE), acrylonitrile-butadiene-styrene copolymer (ABS) or polycarbonate (PC).

Nowadays, new studies are being carried out and new materials are sought to improve the thermal and mechanical properties of the helmets. A good candidate for making the helmet cap is bismaleimide. This new material presents a number of advantages such as: high thermal stability, nonvolatility and low cost (Ursache et al., 2012). The purpose of this paper is to present the thermal properties of a new material, a glass fiber reinforced bismaleimide composite material (BISM COMP) obtained by some of the authors of this work, a material used to manufacture the helmet caps used by firefighters.

2. EXPERIMENTAL DETAILS

The material analyzed in the present paper was obtained by hot molding process, as a composite of glass fiber reinforced bismaleimide. The bismaleimide resin precursor (BMI) were prepared by reaction of 4,4-bismaleimidodiphenylmethane with 4,4-diaminodiphenyl methane. Silica cloth was impregnated with a 50 wt. % solution of BMI pre-polymer in N-methylpyrolidone and allowed to dry for 24 h at room temperature and in a circulating air. The pre-pregs dimension 100x100 mm were packed over the female part of the steel mold coated with silicone release agent. The male counterpart of the mold was placed between the preheated plates (140°C). The first laminate samples were obtained in sheets consisting of a single layer and by pressing several layers followed by heating the samples were allowed to cool down to room temperature gradually under a pressure of 10 Kgf/cm2 and the second type, of multilayer samples, were obtained (Ciubotariu-Ana et al., 2018) Thermal analysis was performed by differential scanning calorimetry (DSC) and mechanical-dynamic analysis (DMA). Tests were performed on two types of samples: samples from a fire-fighting helmet bought from commerce (HDPE) and samples made from glass fiber-reinforced bismaleimide composite (BISM COMP).

For DSC analysis, the DSC F3 Maia calorimeter (Fig. 1) supplied by NETZSCH, with a sensitivity of <1μW, temperature accuracy: 0.1 K and enthalpy accuracy - generally <1%, was used. The device was calibrated with Bi, In, Sn, Zn and Hg.

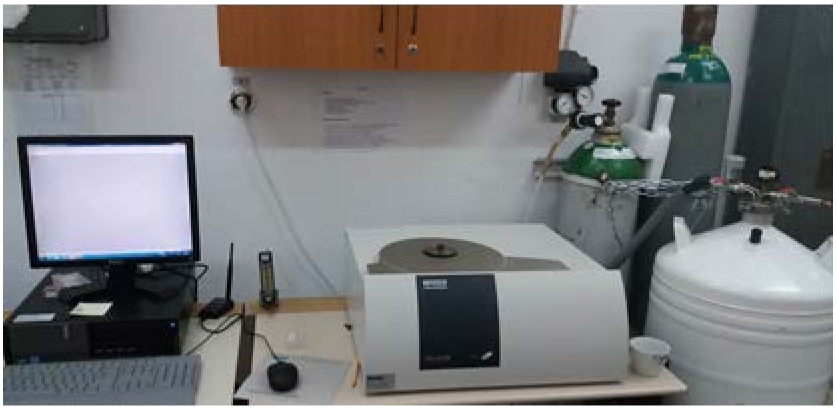

Fig. 1. DSC calorimeter used for experiments

The measurements were performed under Ar-protective atmosphere using corresponding correction curves. The DSC data was evaluated with Proteus software provided by NETZSCH. Small samples with a maximum mass of 25 mg were cuted.

After they have been cleaned from impurities, they were subjected to controlled heating with a 10K/min heating rate up to 400K for the HDPE sample, and 450K for the BISM COMP sample.

For DMA analysis, a dynamic mechanical analyzer (DMA) type DMA 242 Artemis supplied by NETZSCH was used (Fig.2), with a force resolution of 0.0005 N, amplitude range: ± 0.1 to 240 μm and amplitude resolution: 0.0005 μm using a three-point-bending specimen holder.

Fig. 2. DMA analyzer used for experiments

3. RESULTS AND DISCUSSIONS

The DSC thermogram illustrating the heating behavior of the HDPE sample is shown in Fig. 3.

During heating, it can be seen that the sample taken from a helmet bought from commerce has a minimum endotherm at 383.4 K, which is attributed to the melting of the material. For common commercial grades of medium and high density polyethylene, the melting point is typically between 280 and 300 K (Chianelli-Junior et al., 2013). The amount of heat absorbed during this transformation is about 1 J/g.

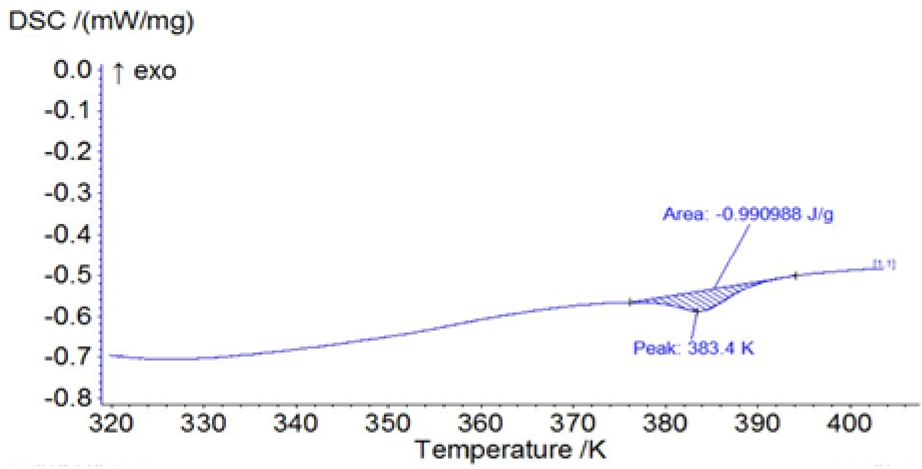

Fig. 3. DSC thermogram recorded during heating for the HDPE sample

In case of heating the sample made from BISM COMP, Fig. 4, the DSC thermogram shows no deviation from linearity that could suggest the presence of a transformation in the temperature range under analysis. It can be argued that the BISM COMP material is thermally stable up to 450 K

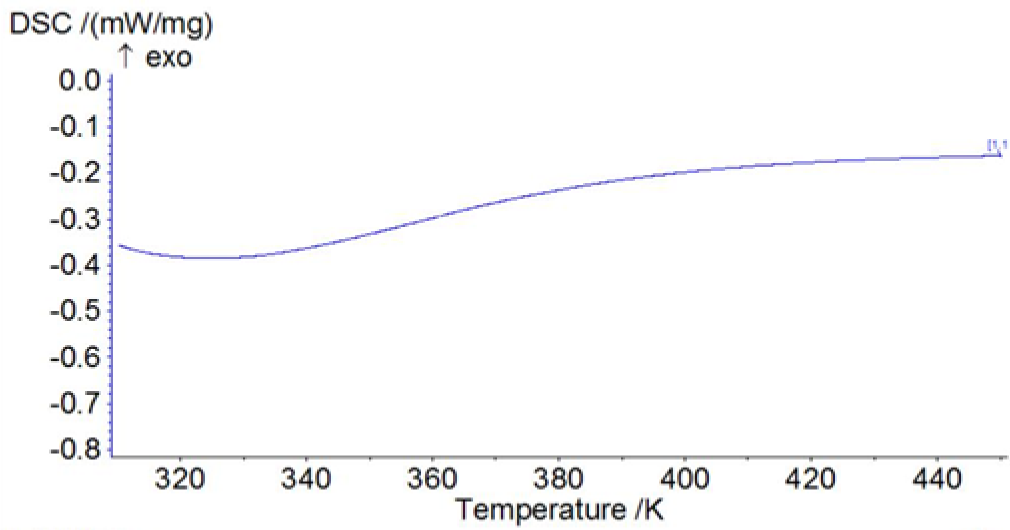

Fig. 4. DSC thermogram recorded during heating for the BISM COMP sample

To verify the visco-elastic behavior of the analyzed samples, DMA experiments were performed. For the analysis was chosen the variation of storage modulus (E'), and the internal friction (tan d) with temperature. In Fig. 5 shows the variation of module E 'for the two analyzed samples. For a better understanding of the dynamo-mechanical properties, an overlap of the elastic modulus (E') was realized for the two samples.

From Fig. 5 it can be seen that the modulus E' value for the BISM COMP sample has values approximately 9 times higher than HDPE. Also, during heating, the sample retains its stiffness in the temperature range of 300-450 K without taking any softening, a requirement imposed to protective helmets. The high levels of the elasticity modulus (about 11 GPa) of the resins bismaleimide are similar to those reported in the literature (Shibata and Hashimoto, 2017).

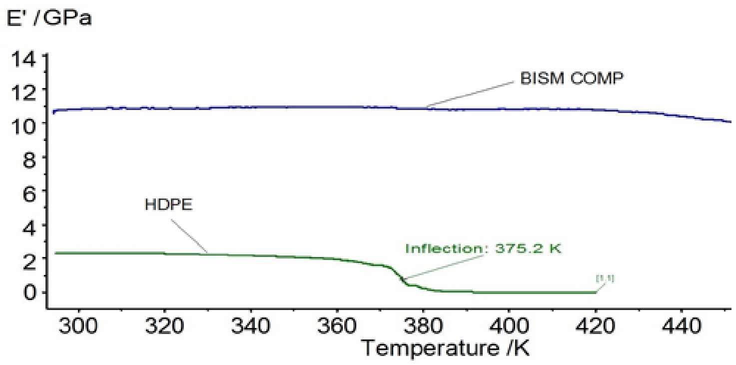

Fig. 5. E’ variation with temperature recorded during heating for the HDPE and BISM COMP samples

On the other hand, the HDPE sample shows a decrease in the modulus between temperatures of 370 -380 K, confirming the recorded melt on the DSC thermogram in Fig. 3. Analysis of tan d curves is very useful in determining of the performance to stress and temperature of the samples. Fig. 6 shows the tan d curves corresponding to HDPE and BISM COMP samples.

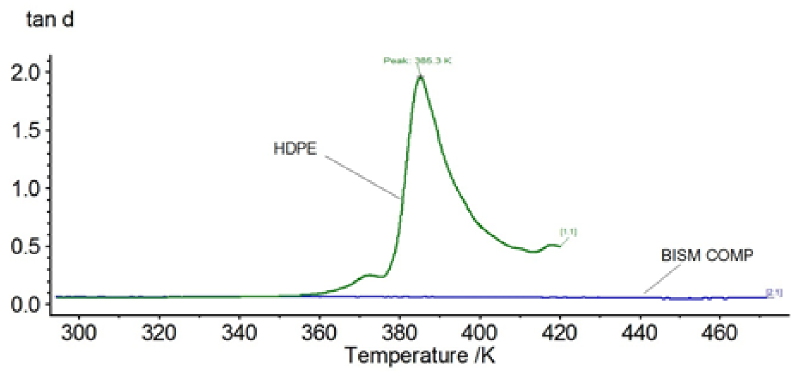

Fig. 6. Tan d variation with temperature recorded during heating for the HDPE and BISM COMP samples

It is clear that in the temperature range studied between 300 and 460 K, the variance of tan d for the BISM COMP sample shows low values. This can be attributed to improved interactions and modified stress transfer. It also explains the values obtained for stiffness by the BISM COMP material (Tian et al, 2017).

It follows that BISM COMP does not undergo any transformation in the area of the analysed temperature while the HDPE sample exhibits a maximum at 385 K, attributed to the melting of the material, according to the data obtained in Fig. 3 and 5.

4. CONCLUSIONS

In this paper we examined the thermal and mechanical dynamics of two samples of material for the fire helmets: a sample taken from a helmet bought from commerce, and a sample of a new material developed by the authors. In summary, the following conclusions were drawn:

- the new material, BISM COMP, exhibits improved thermal properties compared to the materials on the market, proving a superior thermal behaviour;
- during DSC analyses the BISM COMP sample did not show any phase transformation in the temperature analysed field, being thermally stable;
- during DMA analyses, the BISM COMP sample showed an elastic modulus approximately 9 times greater than the sample with which it was compared;
- improved thermal performance makes BISM COMP a good candidate for developing the cap of fire helmets to improve the user safety to high temperatures.

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PIPE MANUFACTURING PROCESS NOISE AND VIBRATION DETERMINATION CASE STUDY

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NICOLETA-MONICA LOHAN [4]

Abstract: Due to the continuous developments in both science and technology, arises a high importance in organizing human activity at the workplace. Two of the most aggressive factors in the workplace are noise and vibration. The noise problem is quite prevalent today because there are a lot more jobs available in industries with a high level of hazard, and so is the number of exposed workers. The purpose of this paper is to analyze the noise and vibration levels in the pipes manufacturing process measured at SC Pipes SRL from Iasi. Following the field measurements taken in the factory, it has surfaced that in some sections, the noise level has exceeded the maximum level of exposure set in Government Decision (GD) 493/2006. Regarding the vibration exposure measurements, it was found that all measurements were within exposure levels set in (GD) 1876/2005.

Keywords: *noise levels, vibrations levels, pipes manufacturing*

1. INTRODUCTION

The continuous development of industrial technology led to a more focused organization of human activity at the workplace. Noise and vibration represent some of the most aggressive physical factors in the workplace. The noise and vibration problems are still prevalent, altho, recently, the number of workers exposed have diminished thanks to the replacement of obsolete machines and equipment that produced intense noise with modern ones, where these pollutants are, usually, within allowed limits (Munteanu 2007).

Sound represents mechanical vibration propagating though an elastic gaseous, liquid or solid medium through which the source energy is transferred by progressive sound waves. Whenever an object moves or vibrates, a small proportion of the energy involved is lost to the environment in the form of sound (Kovacs 2017). Noise is an

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unwanted sound that is defined as a mixture of sounds, strong, discordant, unpleasant, being characterized by intensity (dB) and frequency (Hz). Noise and vibration are generally accepted, due to the professional obligations, but, in most cases, humans will carry on doing their work ignoring ambient noise and vibration (Munteanu 2007). Noise is a major problem for the work force, causing hearing loss, discomfort, sleep disorders, fatigue and hypertension. Although extra-auditory effects of exposure to high noise levels have been reported, noise induced hearing loss has been recognized for a long time as a primary effect of excessive noise exposure (Hong et.al, 2013). With the increase in intensity, noise is felt and can have an adverse effect on a person's professional performance. An unexpected or intermittent noise bothers more than a continuous one, and high pitch noises are more bothering that low frequency ones (Munteanu 2007).

Industrial vibrations are an oscillatory type of movement of solid bodies in an elastic environment, these can be found in most work environments and, like noise, have a negative effect on human body functions (Palmer and Bovenzi 2015). In practice, vibration studies gain a growing weight, due to increasingly prevalent trends (Zhao and Schindler2014, http://www.medtorrents.com), like: (i) equipment with higher performance, higher working speeds and higher dynamic stability; (ii) making buildings as light and safe as possible; (i) protecting human operators. Due to increased power and working speeds of equipment, through the development of modern work techniques, a varied number of sources of noise and vibration have emerged, which led to an increase in the number of persons exposed. Occupational exposure to vibration has many forms and quite frequent in the population. Vibrations can have adverse effects to human health which can manifest through rheumatological afflictions (Palmer and Bovenzi, 2015) or musculoskeletal disorders (Charles et al., 2018). By initiating measures to improve conditions in the work health and safety field, directives have been elaborated on specific areas, stipulating minimum requirements to ensure an optimal level of protection for workers (Kovacs 2017).

Risk identification and assessment is required to determine the protective equipment the workers are required to wear (Ivascu et al., 2014, Moraru et al. 2013), followed by proper use of equipment training (Darabont et al., 2017a, Babut et al., 2011). The correct implementation of the standards in effect (Darabont et al., 2017b, Bejinariu et al. 2017a) is also required.

In this context, the paper analyses the level of noise and vibration in the pipe manufacturing process. For this purpose, vibration measurements were made on the straightening machine, the analyzed area – the drawing roller area and the tube forming area, as well as the noise measurements in the first section of the analyzed company.

2. METHODOLOGICAL APPROACH

Research has begun in the context sketched by competition, based on the idea of profit and sustainable development that imposes limitations through regulation and standards on noise and vibration, which involves additional cost; so, the context is previsely the fierce confrontation between the idea of profit and the costs caused by the reduction of noise and vibration. The area of application is in the metallurgical industry, mainly in pipe making, which is under pressure of sustainable development (Corăbieru 2009).

The methodological approach was based on explanations and understanding, and, the main epistemological references of the paper being:

- the interpretativeist paradigm – to understand reality;
- the constructivist paradigm – emphasizing on building in anticipation of some tendencies;
- the positivist paradigm, used as an exception for deductive explanation (in relation to the theory).

As an epistemological approach, the paper has concluded between ethical and emical as follows:

- through the ethical approach, the general characteristics of noise and vibrations are invoked (intensity, frequency), by identifying the specific characteristics for each analyzed work in order to highlight the elements of general applicability (accepted level of noise, level accepted by vibrations);
- through the eco-type approach, the importance of the measured and analyzed noise and vibration characteristics were highlighted for each work station from the technological work flow, identifying the specific levels in the different groups of activities carried out in the pipe manufacturing process emphasizing the interpretative comparative side.

The two approaches are not entirely in opposition to eachother, being presented during complementary research, relying on each other.

The methodological support for the sutdy was provided by the specialized literature presented by (Mihai-Adrian et al., 2017, Darabont et al., 2017, Babut et al., GD 493/2006, GD 1876/2005):

- fundamental works by specialized personnel from home and abroad;
- periodical publications, analytical and informative;
- legislative acts of the Government of Romania;
- statistical yearbooks, official reports;
- European environmental directives;
- noise and vibration current legislation.

The research techniques were mainly based on comparative analysis, change analysis, prognosis and optimization of the equipment design on the technological flow of pipe making, modelling and simulation in the design of pipe-type products in order to achieve an explanatory and predictive construction.

The method plan is based on the inductive and the deductive method by mixing the qualitative and the quantitative approach.

3. CASE STUDY

The current paper analyses existing noise and vibration in the SC PIPES SRL company, a medium sized company with up to 300 employees and a yearly turnover of over 10 million €. Within the company, the pipe and profile making processes were followed and the physical emissions were measured and analyzed, with emphasis on determining the noise and vibration levels (Corăbieru and Minciună, 2018).

SC PIPES SRL manufactures steel longitudinally welded pipes from hot or cold-rolled strip, on German, Russian and Italian lamination lines. The company also runs cold rolled profiles, has high-quality technologies and its own research center.

The SC PIPES SRL company is includes of 6 sections: Section I – 5 production halls, Section II - 8 production halls: Section III - 6 halls: Section IV - 11 halls, Section V - 5 halls: Section VI - 2 halls.

3.1. Determining the vibration level

Measuring the vibration level was tone in the straightening machine and in the pipe formation areas. The straightening machine (Fig 1a) is an assembly, and, is part of the rolling line; the ribbon is straightened in order to obtain a correct sizing line and to avoid defects or tears. The workers that are handling this machine are subjected to noise and vibration, especially hand and eye protection (Bejinariu et al., 2017b).

In this sense, vibration determinations were made on the drawing rollers. Vibration measurement bulletin for the workplace: the straightening machine is shown in Fig. 1 (b).

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Abilitarea Ministerului Sanatatii nr. 19710 / 24.09.1999

BULETIN DE DETERMINARI NR. 25 /

Unitatea: SC PIPES SRL

Locul de munca: **MASINA DE INDREPTAT**
Iluminatul natural (prin ferestre) si artificial (fluorescent).
Procesul de productie s-a desfasurat in conditii normale.
Timp de lucru 8 ore.

Nr. crt.	Locul de munca	Noxa	Metoda de masurare	Timp de expunere	Aparat folosit	Valoare	
						masurat	admis
1		Vibratii pe axa Z	Momentan	8 ore	SLD 800	0,90 m/s²	1,15 m/s²
2		Vibratii pe axa X	Momentan	8 ore	SLD 800	4 m/s²	5 m/s²

CONCLUZII:

La punctele nr.1 si 2 se vor respecta prevederile art.13 si 15 din HG nr.1876/2005.

Determinarile s-au facut in prezenta urmatoarelor persoane:

DIRECTOR,
ing. Sabau Radu

EXECUTANT,
ing. Sabau Radu

INTOCMIT,
ing. Sabau Radu

REPREZENTANT UNITATE,
ing. Minciuna Gheorghe

Fig. 1. Work place vibration measurements: the straightening machine (a) and the calibration bulletin (b)

The measuring method used was: momentary, with an exposure time of 8 hours. The vibration measurements were made on the Z and X axis. No exceedances for vibrations were found, however, compliance with HG 1876/2005, art. 13 and 15 was recommended.

The machine's rolling speed gradually increases with each strip deformation step. Due to the speed increase on each step, there are noises and vibrations that need to be diminished or eliminated if possible. If the machine tuning isn't done properly, the noise and vibration levels increase and can cause professional illness, discomfort, fatigue, stress, etc.

In this section, vibration measurements were made using the momentary measurement method, with an exposure time of 8 hours. The vibration measurement was carried out on the Z and X axis. Figure 2 shows the analyzed work area (a) and the vibration test report (b). No exceedances for vibrations were found, however, compliance with HG 1876/2005, art. 13 and 15 was recommended.

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BULETIN DE DETERMINARI NR. 25 /

Unitatea: SC PIPES SRL

Locul de munca: **Batiu - formare a tevii**
Iluminatul natural (prin ferestre) si artificial (fluorescent).
Procesul de productie s-a desfasurat in conditii normale.
Timp de lucru 8 ore.

Nr. crt.	Locul de munca	Noxa	Metoda de masurare	Timp de expunere	Aparat folosit	Valoare	
						masurat	admis
1		Vibratii pe axa Z	Momentan	8 ore	SLD 800	1,0 m/s²	1,15 m/s²
2		Vibratii pe axa X	Momentan	8 ore	SLD 800	4,5 m/s²	5 m/s²

CONCLUZII:

La punctele nr.1 si 2 se vor respecta prevederile art.13 si 15 din HG nr.1876/2005.

Determinarile s-au facut in prezenta urmatoarelor persoane:

DIRECTOR, ing. Sabau Radu

EXECUTANT, ing. Sabau Radu

INTOCMIT, ing. Sabau Radu

REPREZENTANT UNITATE, ing. Minciuna Gheorghe

Fig. 2. Analysed work area: (a) the pipe forming area; (b) vibration measurement bulletin for the pipe forming area work station

3.2. Determining the noise level

Noise measurement have were taken in section 1, work station and sales service. Resulting from these measurements, it was concluded that there were exceedances of noise levels and that there were some jobs in which the exposure was over the admitted levels. In these places, employee activity was forbidden according to HG 493/2006. Fig. 3 contains the determination bulletin.

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e-mail: dsp99@dspiasi.ro, www: dspiasi.ro
Serviciul: Evaluare factori de risc din mediul de viaţă şi muncă
Compartiment Medicina Muncii
Operator de date cu caracter personal nr.11730

BULETIN DE DETERMINARE Nr. 52

cuprinzând valorile de zgomot înregistrate în data de 07/2017

la SC PIPES SRL

Aparatura folosită: Sonometru integrator "Quest Industries" serie OHOSO110022

Nr. Crt	LOC DE MUNCĂ	LEQ1	LEQ2	T1	T2	T-t	LEQ/zi	LMA
I.	SECŢIA I							
1	Hala 1- LPB 11 - pupitru	97.1	72.7	5	3	8	95.06825	87
2	- cabină comandă	89.3	69.9	7	1	8	88.7272	87
3	Hala 2-Ajustaj gr.Sanfrenat, pat control - ajustaj	98.7	75	7	1	8	98.12273	87
4	- suflare span ţeavă	117.5	77.2	2	6	8	111.4806	87
5	Hala 2 sud - Colector 220 - pupitru	86.6	69	7	1	8	86.03085	87
6	Hala 2 - Alimentare 220 - pupitru	85.6	64.6	7	1	8	85.02501	87
7	Hala 5 - Liniile 30l. 30xU - laminator	82.8	63	7	1	8	82.22657	87
II.	SECŢIA a II-a							
8	Hala 10 - Ajustaj 89 pat control - op. verif. ţevi	89.5	70.1	7	1	8	88.9272	87
9	Hala 11 - RAC 89 - cuptoare	86.9	69.2	7	1	8	86.3306	87
III.	Secţia Mentenanţă Preventivă, Predictivă, Statii							
10	At. piese schimb - maşină frezat universală	86.2	68	6	2	8	84.97247	87
IV.	SECŢIA STAŢIA							
11	Camera pompelor	90.3	70	3	5	8	86.10734	87
12	Staţie compresoare - mijloc sală	88.5	69.6	4	4	8	85.54529	87
13	- atelier reparaţii	79.3	65	4	4	8	76.44813	87
V.	SERV. VANZARI							
14	Hala 9 - Depozit 99 - op. încărcare ţevi	81	60.9	4	4	8	78.03193	87
15	Hala 3,4 sud - Depozit 97 - op. încărcare ţevi	83.9	65	4	4	8	80.94529	87

Interpretarea determinărilor s-a făcut conf. HG 493 / 2006.
Valorile haşurate sunt necorespunzătoare .

LEGENDA

La aceste locuri de muncă s-a depăşit nivelul valorii de expunere de la care se declanşează acţiunea. Se impune luarea masurilor conform HG 493/ 2006 .

La aceste locuri de muncă s-a depăşit nivelul valorii limită de expunere . Este interzisă activitatea angajaţilor în aceste condiţii, conform HG 493 / 2006.

La aceste locuri de muncă valorile se încadrează în limitele normale.

Intocmit: as.pr.igienă,
[illegible] Iulian & Tăbăcaru Andrei

Fig. 3. Workplace test report: Section I

3.3. Workplace health and safety policy

The core value promoted by SC PIPES SRL is the creation of a healthy work environment that ensures the development of the organization and the professional and personal development of the employees. The company's target is zero accidents. Prevention of Accidents and Occupational Diseases underpins the drafting of the Health and Safety Policy of SC PIPES SRL.

The main concerns for fulfilling the principles of the Health and Safety Policy are:

- Employee awareness regarding accident risk and workplace illness, related to the activities they are involved in and a continuous care for reducing and eliminating risks;
- Health and Work Safety trainings and workshops;
- Emergency situation simulations;
- Continuous employee consolation on workplace safety and health issues;
- Initiatives to motivate the employees in promoting safe working practices and contribution to the creation of safer jobs.

4. CONCLUSIONS

The measurements yielded the following conclusions:

1. Noise and vibrations aggravate and maintain pre-existing conditions such as anxious obsessions, nerve depression in depressed patients, gastro-duodenal conditions, and especially unexpected noise can cause major seizures and epilepsy.
2. Noise and vibrations directly reduce work capacity by reducing intellectual concentration, lowering precision and efficiency of movements, decreasing or distracting attention, increasing energy expenditure needed to perform a given physical effort, difficulty in perceiving verbal information (orders, assign task) voice and cerebral overload.
3. Measures to combat noise and vibration must be directed to removing or reducing the action of the indicated causes. If it is not possible to carry out radical measures, measures must be taken to isolate and absorb the noise from production. The sound absorbing material must have a maximum absorption coefficient. It is recommended that, where possible, noise work be carried out in the open air.
4. Proper machine balancing can remove the action of noise and vibration factors. It is possible to install on special elastic basis the machines and equipment that cause noise and vibration and at the same time to separate them with a layer of air from other rooms of the building.
5. Interpretation of the determinations carried out at SC PIPES SRL was made in accordance with GD 493/2006 and GD 1876/2005 and it was found that in the case of noise measurements in some workplaces the level of the exposure value at which the action is triggered was exceeded (Section 1 - Hall 2, collector, Hall 2 - 220-desk power station, 30L lines, 30xU-laminator, Hall 11-RAC 89-ovens, pump room, compressor station).

6. Following the interpretation of the results, it was found that some workplaces exceeded the limit value for exposure to noise. Thus, the activity of the employees is forbidden.
7. As far as the results of the vibration bulletins were concerned, it was found that all measurements were within the limits of exposure to vibrations.

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Scientific Reviewer:
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OPERATING ENVIRONMENT IN AUGMENTED REALITY MAINTENANCE APPLICATIONS

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NICU-GEORGE BIZDOACA [3]

Abstract: The year 2018 brings new challenges to the use of current technologies. Since very old times the human kind craved upon reaching the furthest goals, usually those it only dreamed of. To be able to accomplish, the human invented and implemented ways to bring him closer to his ultimate goal, namely, knowledge. Augmented Reality (AR) is the mean by which an idea, a concept or even a thought can be translated into a more interactive manner for the user. This paper brings to the forefront the use of Augmented Reality in an area where the barrier between material world and imagination is overcome, so a multitude of applications can be developed. The range of applications can begin by simulating simple scenarios for learning purposes to an immersive and complex virtual environment which will educate users to be able to react in extreme or dangerous situations. Conclusions available in the end of the paper will uncover the perspectives offered by introducing the AR as an operating environment in maintenance applications.

Keywords: *Augmented Reality; environment; application; technology; maintenance*

1. INTRODUCTION

Although the augmented reality is not a relatively recent discovery, it has only recently grown and made itself remarkable throughout the world wide within a rather short time.

Having an early quite modest stage because device processing power was still premature and could not provide means for the full performance of the Augmented Reality, with the development of technology and mobile devices, this kind of reality has come to the hands of the ordinary user getting him used to what would come next, namely the development of a new type of reality.

One of the first applications which used this concept and made itself known was the scanning of QR barcodes. With a smartphone's camera, such code can be scanned

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and the information contained can be decoded. Of course, the performance of augmented reality is not just about the ability to get information from QR codes but can be extended to introducing 3D objects in the scene with the help of a graphic engine. Objects can be either static or dynamic, which means that interaction with them will allow manipulation in a convenient way for the user.

At a first look, AR seems to be a fictional area but it has become possible and accessible to the general public with the evolution of smartphones and gadgets capable of delivering such technology. AR can show its true contribution to areas that require a high level of complexity, reduced accessibility in the event of a large geographic spread of equipment to be maintained, difficult know-how exchange between experts and technicians and high costs of intervention for maintenance.

As with the word "*only sky is the limit*" the development of applications that will use this concept is limited only by the imagination of the developer. This paper aims to develop an application that will offer support to the personnel responsible of activities in maintenance applications.

2. CONCEPT

Paul Milgram defines Mixed Reality (MR) as an environment in which the real world mixes with the virtual one and the result is displayed in one form, MR being the border between the two. Although MR offers both reality and Virtuality Augmentation (VA), the paper brings to the forefront the use of Augmented Reality.

Augmented Reality is part of Mixed Reality (MR) (Fig.1) and stands as a new concept that combines both software and hardware technologies which intend to improve the work environment and the workflow resulting in an enhanced labour quality. The idea of AR implies the use of optical devices assisted by the processing power of electronic ones to allow the overlay of 3D or 2d graphic elements over real objects. The result obtained through implementing this concept will be an improved environment providing more information and functionalities, which will allow a more precise interaction with it.

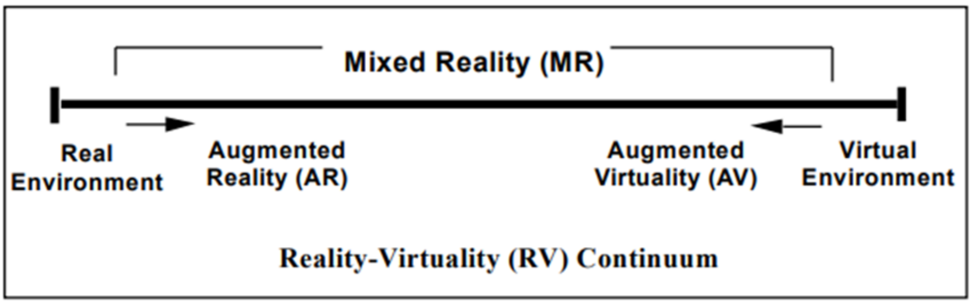

Fig. 1. RV Continuum

In fact, the AR is a live physical sight in which graphical elements developed on the computer are overlapped on real-world elements producing the semi-immersion of the user and stimulating his senses causing him to acquire new skills and support him in his activities.

3. APPLICATION

In developing such an application, key elements are needed to have a guaranteed success and to achieve the targeted purpose. Although the number and nature of the elements may vary from one application to another, their identification must be done correctly in order to have a final product with a great impact and increased utility.

Analysing the process which shall be supported by such an application must take place first and foremost because the data obtained can determine the type of objects to be designed and the type of interaction that will take place between user and application. Also, the analysis should consider the experts' opinion and the challenges they have faced over time. Not only the process analysis needs to be done in this manner, but also the development of the application. This must be done in close contact with technical process representatives who can provide a clear and accurate diagnosis over support information which shall be provided to the targeted personnel that will make use of the application.

This paper focuses mainly on the development of a maintenance application for the industry and also for the equipment that implies special attention and meticulous care, with the possibility of customizing according to the process needs and field of activity.

One way to develop an application which will deliver an augmented reality is using ArCore platform, the official and supported platform offered by Google. This platform targets Android compatible devices and will make use of its hardware for interpreting and understanding the environment. When using this library, every motion of the device is recorded and based on the input data coming from the sensors, the application creates a context similar to the real world but which allows alteration. At this point the basic setup is done and the next stage of development implies addition of new virtual elements in the scene.

For an experience rich in performance and high quality graphics ArCore can work with two compatible and powerful graphic engines, Unreal Engine and Unity 3D.

With the help of such an application, two major aspects are fulfilled, namely tele-maintenance and training of the designated personnel. By means of tele-maintenance, the information exchange takes place much faster and easier and the tasks are carried out more efficiently which in the end increases productivity. Also for productivity purposes, the application provides unconditional support to the service personnel training the with the correct skills necessary for the maintenance tasks.

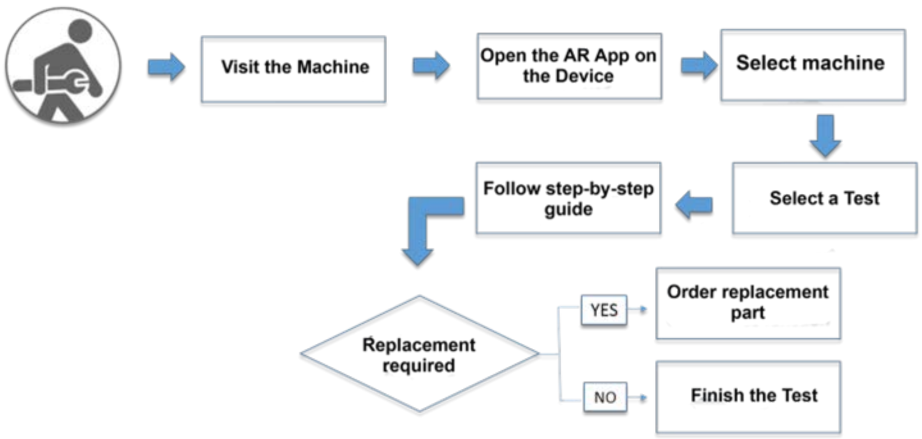

Fig. 2. AR application workflow

The application aims to support the user by presenting a predefined interactive scene using a device capable of rendering augmented reality. The interactive scene presents itself as a graphical step-by-step guide for operating and manipulating a particular component in order to perform a maintenance operation, thus managing to provide the appropriate support (Fig.3).

Fig. 3. AR application layout

4. CONCLUSION

This paper presents the development and the perspectives offered by an operating environment in Augmented Reality maintenance Applications that can be used by less experienced technicians or users in different situations that typically require specialized expertise in maintenance problem solving.

The perspectives offered by developing such an application comprises and is not limited to:

- A mixed reality and semi-immersive experience
- Information available at a click away
- Training of the designated personnel in solving technical problems
- solving situations and maintenance problems in a short time, without any other cost / cost reduction
- Improves customer satisfaction - assures the assistance of any type of user (technical and non-technical)
- reproduces scenarios according to the specifics of the company or the work environment
- Ensure a higher level of knowledge transfer (know-how)
- Reduces errors and periods of inactivity in complex operations
- Provides accurate maintenance in a short time

Thus, the Augmented Reality technology incorporates a portable device with just one click away for any maintenance work required for a company's specificity.

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DEVELOPING A MODEL OF OCCUPATIONAL HEALTH PROGRAM

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Abstract: The first author of this paper noted last year, in a workshop at the MSE 2017 international conference on OSH-related topics, that none of the experts involved and any papers on this topic did not focused on the occupational health component, focusing especially on occupational security. We affirm this because both the national legislation in force and the OHSAS 18001 standard deal with both aspects. Starting from this observation, the authors propose a model of occupational health program intended especially to help companies reduce the costs of absenteeism on case of illness and which could also positively change employee perceptions over the employer and why not in this context could lead even to thereof higher performance.

Keywords: *occupational health, modelling, therapies, improving the health of employees*

1. INTRODUCTION

Concern for employee health is often a neglected process, in some ways, by employers (we are talking, especially, about employers in Romania). It is not explicitly specified in the legislation that the employer should also consider this aspect. An example would be Article 27 of Section 4 named Internal Prevention and Protection Services under Law 319/2006 specifying: "The Internal Prevention and Protection Service may also provide for the supervision of the health of workers if they have staff with professional and appropriate material means, according to the law ". Another example could be that although in this law the word health or its variants is mentioned not less than 339 times and only about 1% this word occurs independently of the expression health and safety at work.

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Throughout the experience in the field, we have heard, often, that health is the responsibility of the physician, in way of the health of the employee, is the responsibility of the occupational medicine doctor. So we (persons/employees/employers) have nothing to do and we should not get involved. It's not like this...?

Following a more detailed analysis of this phenomenon, we have concluded that the above-mentioned process, namely the concern for employees' health if brought to the spotlight, may become a factor, not negligible, of increasing the profit of an organization. We refer here in particular to the possibility of reducing the costs of paying sick leave for the employer (the first five days of temporary incapacity to work under Law No. 399 of 30 October 2006 for the approval of Government Emergency Ordinance No. 158/2005 on leave and health insurance benefits). Of course, we must also take into consideration the problems generated in the organizations by sickness absenteeism.

Taking these issues into account, we generated a model of occupational health program in order to facilitate the cutting down of the cost of absenteeism linked by the sickness in companies.

2. CONCEPTUAL MODELING OF AN OCCUPATIONAL HEALTH PROGRAM

2.1. General aspects

At present, organizations are struggling for survival and supremacy on the market. The winners of this struggle were and are the organizations that have managed to create a discriminator in their sector of activity. Thus, successful models have emerged as sufficiently flexible and adaptable to market conditions, according to Zerbes, 2017. Marcu, 2002 defines the model as an ideal or material system by means of which the properties and transformations can be studied by analogy or by mathematical calculation to another more complex system and / or process. In other words, a model is a simplified representation of a process or system according to the definition of the "Iorgu Iordan - Alexandru Rosetti" Institute of Linguistics within the Romanian Academy, 2009.

The objective of a model is to predict with a certain degree of accuracy the behavior of a system / process. The accuracy of a model depends, among other things, on: the accuracy with which everyone wants to know the system / process running, the time available, the necessary money, the accuracy of the input data, the calculation facilities, etc. Lobont said in 2002.

Taking into account all this and their experience, the authors of this paper have developed a model of health program meant to become, as we have already said, a discriminant for the organizations that will use it. The model, generically named IAP-IAP, is briefly presented below.

2.2. Brief presentation of the proposed model

The acronym IAP-IAP derives from the original model developed by the authors shown in Figure 1:

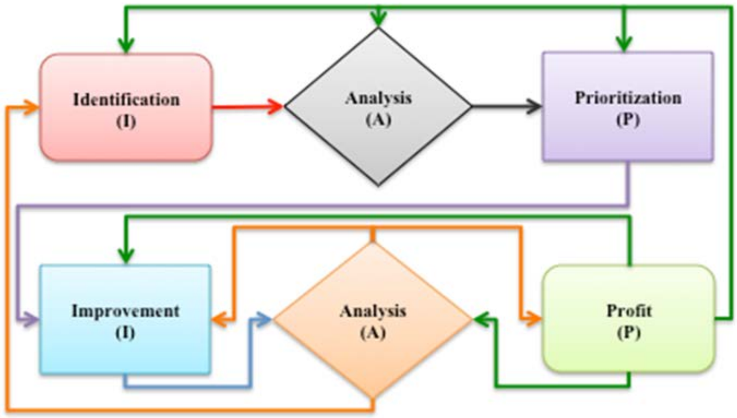

Fig. 1. The general model

Starting from the general model, we have developed a model specific to occupational health (OH) as follows:

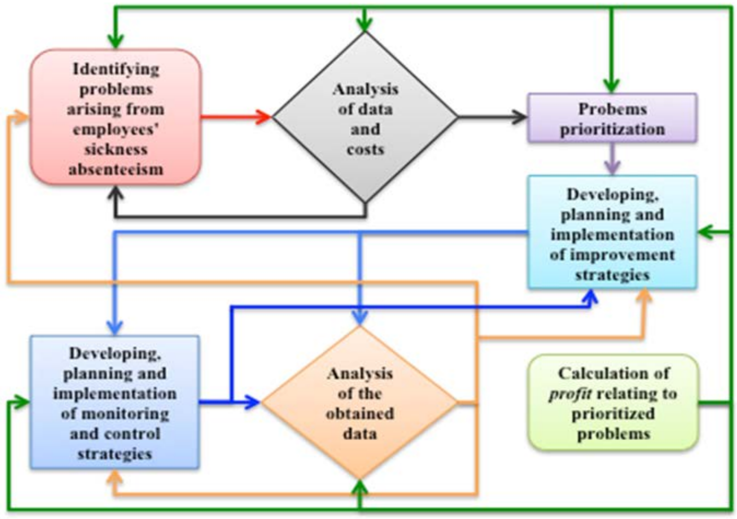

Fig. 2. OH specific model

2.3. Detailed model presentation

For a better understanding of the model and its mode of operation, we present the model in 3 distinct but complementary forms: graphic, tabular and mathematical.

The graphic model is shown in Figure 3 as a flow diagram and aims to highlight the steps in which the modeling process takes place and the relationships between them.

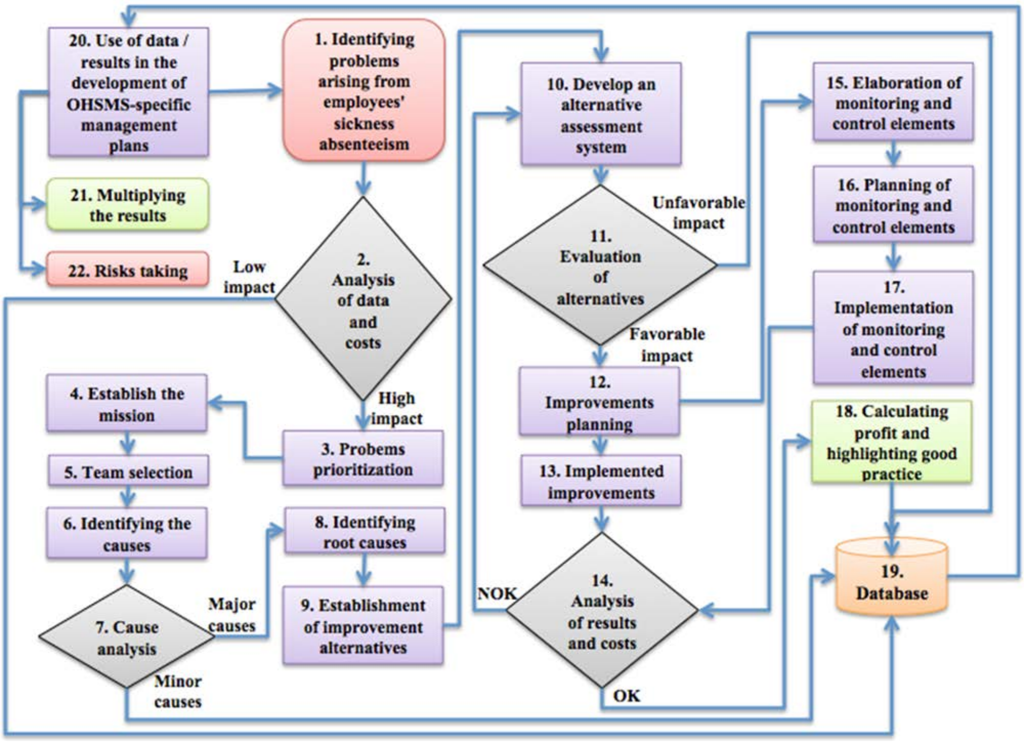

Fig. 3. Steps of the modeled process

Because the lack of space (due to the drafting restrictions) we only present the way of building the tabular model (table 1). We also took into account the fact that the specialists from the organizations that will adopt it can personalize the tabular model.

Table 1. An example of a table

Activities	Recommended methods, techniques and tools	Aim	Performance indicator	Weighting coefficient	Risk coefficient
A1	A B C . . . X	A1.1	P1.1.1 . . P1.1.m	W1.1.1 . . W1.1.m	R1
		A1.2			
		. .			
		A1.n			
. . . A22	. . .	. . .	. . .	. . .	. . . R22

Mathematically expressed (Zerbes, 2017) the tabular model is presented as:

$$M_{OHP} = \left(\sum_{i=1}^{22} A_i\right) R_i \tag{1}$$

in which:

$$\sum_{i=1}^{22} A_i = \sum_{j=1}^{m} P_j W_j + \cdots + \sum_{y=1}^{x} P_y W_y \tag{2}$$

therefore:

$$M_{OHP} = \left(\sum_{j=1}^{m} P_j W_j\right) R_1 + \cdots + \left(\sum_{y=1}^{x} P_y W_y\right) R_{22} \tag{3}$$

where:

M_{OHP} – OH program model
$P_{j..y}$ – performance indicator
$W_{j..y}$ – weighting coefficient
R_i – risk coefficient

It should be noted that Ri - risk factors might vary from one organization to another depending on several factors such as experience, time priorities, organizational politics, etc.

2.4. Discussion

The conceptual model proposed by us has as its starting point the classical diagram of the process model presented in Figure 4 (Zerbes & Budău, 2005). Thus, it has defined the inputs, outputs, control elements and the mechanisms necessary for the functioning performance of the proposed model.

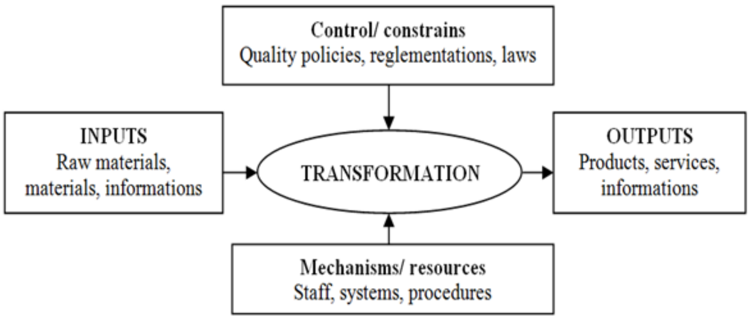

Fig. 4. The classical diagram of the process model

In order to facilitate the processes of regulating and implementing planned improvements, one can use the representation mode called tabular flow diagram (Table 2) to highlight the inputs, outputs and responsibilities associated with each activity in the process. For their establishment, organizations will appeal to internal and external experts, especially for consultants in the field. As we can see, we recommend that you determine the responsibilities to use the Deming cycle (PDCA).

Table 2. The tabular flow diagram

Inputs	Activities	Outputs	Responsibilities (human resources)				
			Plan	Do	Check	Act	Reporting
Resurse: • Material • Financiare • Informationale	Flow chart from figure 3	Rezultate: • Tengibile (rapoarte, procese verbale, instructiuni, dispositive, echipamente etc.) • Intangibile (cunostinte, experienta etc.)	Cine planifica activitatea?	Cine implementeaz a activitatea?	Cine monitorizeaza si controleaza activitatea?	Cine decidecide luarea masurilor de imbunatatire?	Cine raporteaza catre top management?

Regarding the documentation of the planning and implementation activities both of the improvements and of the control elements, we recommend that the organizations use the structure specific to the project management. In this respect, due to the fact that we are actually talking about a project to improve the health of employees, we will consider at least of the following aspects:

- Project title;
- Period of deployment;
- Possible funding sources;
- The project team (for each function involved, the job description will be drafted and a work contract if the team / function comes from the outside of the organization or an annex to them if the team / function is from the inside);
- Partners / collaborators (if it's applicable);
- Target group;
- Project justification (describe the situation of the target group before implementing the project, describe the causes and effects of the identified problem);
- Project beneficiaries (mention the direct and indirect beneficiaries of the project);
- SWOT analysis of the ability of the organization and / or team to solve the identified problem;
- The purpose of the project;
- The objectives of the project (the ways to reach the goal);
- Project results;
- The activities / work breakdown structure (details of the project activities according to the established objectives, pointing for each activity the sub-activities, the resources necessary for their implementation and the related duration);
- Budget (make budget by grouping costs by spending categories - human resource expenditures and material resource expenses);
- Implementation chart (Gantt diagram);
- Daily schedule and description of the activity / function;
- Daily schedule and description / target group (target group), etc.

We mention the fact that the stage of the occupational health program dedicated to the employee will consist in the implementation of integrative therapies and will be complementary to the medical services provided by the doctors of occupational medicine. Consequently, depending on the affections identified at the targeted employees, the program will include specific elements:

- allopathic medicine such as:
    - specialized medical check-ups (eg: cardiovascular, musculoskeletal, digestive system, etc.);
    - investigations;
    - medical tests;
- alternative medicine from practices:
    - Ayurveda;
    - traditional Chinese medicine;
    - homeopathy;
    - acupuncture, etc.
- complementary therapies such as:
    - physical therapy;
    - osteopathy;
    - massage;
    - reflexology;
    - presopuncture;
    - Bowen technique;
    - dietotherapy;
    - phytotherapy;
    - apitherapy;
    - hydrotherapy;
    - hirudotherapy;
    - psychotherapy;
    - sacrotherapy;
    - bioenergotherapy, etc.;
- personal development programs on topics such as:
    - nutrition education;
    - health education;
    - healthy lifestyle;
    - personal hygiene;
    - teamwork and teambuilding;
    - time management;
    - stress management;
    - physical education;
    - maintenance gyms;
    - yoga;
    - aikido;
    - tai chi;
    - qigong;
    - the music;
    - dance;
    - meditative painting;
    - euritmia etc.

3. CONCLUSION

In conclusion, we believe in the efficiency of such programs. In the article *Occupational health programs and workplace absenteeism*, the authors (the same authors as the present paper) present such a program successfully implemented, in a company in Sibiu in the field of software consultancy.

We anticipate that such programs can increase the quality of life by improving service relationships with beneficial effects on all employees by increasing the level of trust in the team and management. Thus, the employer also will win by reducing especially staff fluctuations and increasing the company's profit. It is worth mentioning that without the direct involvement of top management in the organization such programs have no chance of success. However, the employer must first understand the benefits of using such a program and find out the strategies of awareness and motivation of employees who would participate in such a program.

Also, we must not forget the social benefits of such a program, first of all by improving the health status of the community they belong to employees. In this context, we recommend family involvement to increase motivation and ensure long-term compliance.

Finally, in the context of those presented in the paper, is the question from the introduction: Who is responsible for my health (as an individual / as an employee)?

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Scientific Reviewer:
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UNIVERSITY OF PETROȘANI

INDEX OF AUTHORS

INSTRUCTIONS FOR AUTHORS[1]

THE TITLE OF THE PAPER WILL BE WRITTEN WITH CAPITAL LETTERS, CENTERED, AT 7.0 cm FROM THE UPPER EDGE OF A4 FORMAT, ALONG THE ENTIRE WIDTH, TIMES NEW ROMAN, 14 POINTS, BOLD.

· (14 points)

· (14 points)

The first name and the family name will be written with CAPITAL LETTERS, BOLD, CENTERED, 130 mm width, Times New Roman, 12 points, each name being followed by number, *and in the footnote the didactic and scientific degree, the position and place of work of the authors (possibly fax, E-mail) are indicated, with italics, 130 mm width, Times New Roman, 11 points.*

· (12 points)

· (12 points)

<Tab> **Abstract: (Times New Roman, 10 points, bold)** The Abstract will only be in English and will have between 50 and 100 words, arranged all over the entire width, single, left – right alignment, all over the width of the printed space, Times New Roman, 10 points.

· (10 points)

· (10 points)

<Tab> **Key words: (Times New Roman, 10 points, bold)** 5 – 10 words, in English, along the entire width, Times New Roman, 10 points.

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<Tab> **1. THE TITLE OF THE CHAPTER IS WRITTEN WITH CAPITAL LETTERS, BOLD, TIMES NEW ROMAN, 11 POINTS AND WILL BE NUMBERED WITH ARABIC NUMBERS.**

· (11 points)

<Tab> The paper text paragraphs will be left – right aligned. The lines of the entire text will be single spaced with Times New Roman fonts, size 11 points.

The paper will be edited in a language of international circulation (English, French, German) on A4 format (210 x 297), page setup: top 5,6 cm, bottom 4,6 cm, left 3,7 cm, right 3,7 cm, in WORD or WORDPERFET or WINDOWS and the number of pages must be even between 4 and 16. The size of the symbol is given next and is written in the instructions used to assist in editing the text. It indicates a blank line and does not show in the text of the paper, being obtained by pressing <ENTER>. The size of a <Tab> is 1,27 cm. No blank line is left between the paragraphs. Between the last line before the title and the title of the chapter and between the title and the first next line a blank line is left for each.

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[1] *Professor Eng., Ph.D. at the University of Petroşani, adresa email*

<Tab> **1.1 Subchapter. Subchapters can be used in the text, numbered with the number of the chapter and a number showing the number of the subtitle within the chapter. The subchapters and the numbers are Times New Roman, 11 points, bold.**

· (11 points)

The text is written in new paragraph and not continuing the subtitle, an 11 point blank line being left between the subtitle and the following text.

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2. PRESENTATION OF THE FIGURES

· (11 points)

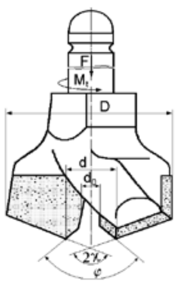

Fig. 1. Detachable bit

Figures should be enclosed in the text in the order of their presentation, as far as possible on the page where reference is made to them. They shall be numbered with Arabic numbers. Black – and – white, high contrast figures are recommended. Photos can be used as well, but they should be of good quality, clarity and sufficient contrast. The figures will have a legend (name of the figure), which, along with the number, will be written underneath with Times New Roman, 10 points, centered as to the figure. The figures will be surrounded by text.

· (11 points)

3. PRESENTATION OF THE TABLES

· (11 points)

The tables will be enclosed in the text, a 10 points blank line being left above and under the table, and will be numbered with Arabic numbers. Both the number and the explanations to the table are written with Times New Roman, 10 points, italic, for the number and bold for the explanation to the table, centered in the space of the table and above it. The table entries will be Times New Roman, 10 points, bold, and the data in the table will be Times New Roman, 10 points. The thin lines of the table will be ½ points (0,02 cm), and the thick ones will be ¾ … 1 points (0,03 … 0,04 cm).

· (11 points)

4. PRESENTATION OF THE MATHEMATICAL EQUATIONS

· **(**11 points)

The mathematical equations will be with times New Roman, 11 points, center of the page and numbered on the right with Arabic numbers between round brackets.

· (8 points)<Blank line 8 point high>

$$X^2 + Y^2 = Z^2 \tag{1}$$

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An 8 point high blank line is left between the last line before the relation and the relation and between the latter and the next first line.

The last page will be at least 2/3 full.

The pages of the paper will only be numbered by a pencil outside the printing space.

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